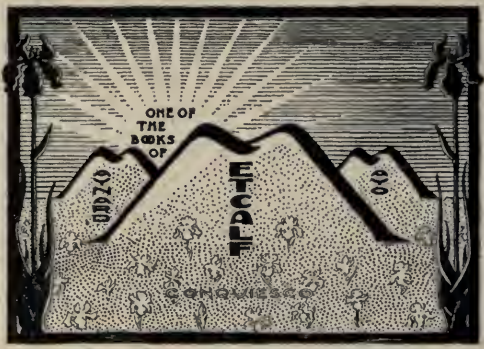
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VIGNETTES

FROM

INVISIBLE LIFE.

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VIGNETTES

FROM

INVISIBLE LIFE.

BY

JOHN BADCOCK, F.R.M.S.

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PREFACE.

THIS is a very pretentious little book. It assumes as a fact that very few even otherwise well-educated people, know anything whatever of the life here treated of; and consequently pretends to convey that knowledge to them, or at any rate to introduce the subject to their notice, and so peradventure awaken such an interest in their minds as shall induce further investigation.

The microscope reveals a new world of life and beauty. "The invisible appears in sight;" and it may be confidently predicted that at no very distant period no one will be considered educated who does not possess a knowledge of its revelations, and that all such who have the means will become possessed of the instrument. Neither, considering the present tendency of the makers to produce cheap and popular microscopes, need the expense be a

hindrance to any steady mechanic or day-labourer that wishes to have one of his own.

The difference between the knowledge obtained from books and that gathered from observation, is immense. In the former you are taking it diluted—or at second hand, at least. In the latter, you have it direct, with all its inspiration, from the "fountain head" or great source of all knowledge. It is superficial and easily forgotten in the one case; while in the other it becomes part and parcel of your intellectual nature, which nothing can destroy. In the one instance, you may become a very "book-worm" and yet *know* but very little—your mind "cribbed, cabined, and confined" with the ideas, prejudices, and systems of other men. In the other, the illimitable expanse of nature opens its glorious vista to your enchanted vision; your spirit bounds with delight; you press forward; you drink from the fountain; your whole being is saturated with divine impressions; you are grasping the sublimest truths and realising the highest bliss of which our common humanity is

susceptible. None will ask the now common question, "Is life worth living?" who will rise to the realisation of such experience as this. With them the impression will be rather that "Life is all too short" to compass but a small portion of the boundless realms of knowledge ever opening up to them.

The desire for *Immortality* is not only awakened —it is intensified by every fresh accession to the store of this divine wealth, and, growing in intimacy, they become one in spirit with the beauty, harmony, unity, order, joy, sorrow, and unspeakable beneficence of the universal Divinity, who, permeating, pervading, animating, directing, and controlling, is the great eternal "All in all."

The great founders of the religions of mankind, and the seers and the moralists, were in their several ways, and according to the means at their disposal, students of Nature. They were, before all things, impressed and inspired by communion with her, and drew thence their loftiest teachings for the guidance of millions. Whatever there is

of good in all the diverse religious systems of antiquity is derived from this source. The truths thus acquired still stand out as gems amidst a mass of rubbish, or as light in darkness, life in death. If in comparative ignorance such results were obtained, what might not be expected and realised with our present means and appliances? With the accumulations of the past as aids and warnings, how much greater should be our success! How *truer* our inferences and *sublimer* our inspirations! This is the goal to which humanity is tending; and to the aiding of this result this little book is offered as one of the smallest contributions by its author.

> "By swift degrees the love of Nature works,
> And warms the bosom; till at last, sublim'd
> To rapture and enthusiastic heat,
> We feel the present Deity, and taste
> The joy of God."

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VIGNETTES

FROM

INVISIBLE LIFE.

I.—PLANT ANIMALS.

"Joy you in fairies and in elves?
We are of that sort ourselves."—CAMPION.

"Full Nature swarms with life; one wondrous whole
Of animals or atoms organised."—THOMSON.

WHAT we have sketched on the next page resembles a tree; but when the drawing is examined certain peculiarities of an exceptional character present themselves. There are the trunk and branches and flowers, but no leaves. But many trees develop the flower first. And then in our sketch there is no sign of leafage; neither are there any roots. Again, the flowers themselves seem to be fringed with hair. Obviously, there is something new and strange about this apparent tree; and it is indeed

remarkable, and hardly known to any but scientific men. More than 200 years have passed since the subject of our sketch was first discovered, yet very few people have heard anything about it, and fewer have ever seen it. The original observers of it and

Fig. 1.—*Epistylis grandis.*

its fellows, at first much puzzled, named them bell-flower animals; and in truth this sketch represents an animal-tree. It seems rather an impossible sort of name. The words "animal" and "vegetable" indicate the two great natural kingdoms into which all life on this globe is divided. Yet here is a name combining the two ideas in one object; but then that is what the object itself does.

Let us describe this "animal-tree." In the particular species we have figured the trunk and branches are rigid, while the flowers are active with all the phenomena of animal life. It lives in water, and in order to get food sets up a whirl or vortex by means of its fringes of cilia. Each flower is a living and active being that selects its own food; and in due time, leaving the colony, wanders off into the world—finally settling down and founding a family of its own. First it will develop a stalk, and fix it to some steady object. Then after a time its activity becomes less; it seems to sleep, and gradually to contract a little longitudinally. This process continues until it has actually accomplished a wonderful feat: it has produced its double—a companion in all respects soon to be its equal, and to assist in the great work of founding a colony in a tree form, complete with trunk and branches like the one from which it originally migrated. Such in brief outline is one of its many transformations—so wonderful that the German naturalist Ehrenberg compares them to that of an old man going through a process by which he should regain all his youth and vigour.

We have seen that the active life is in the flower: the trunk and branches stand in the same relation to it as the shell does to the snail. You may often observe the rigid and flowerless trunk and branches standing bare—all the flowers gone, and life extinct. Some of this class of creatures develop flexible trunks and branches capable of rapid and beautiful changes — ever and anon changing from a wide-spreading forest-like tree to a small and compact mass; others, again, develop only spiral stems, which they attach to the leaves or stalks of weeds. In the composition of all, however, there is more of the animal than of the vegetable.

By this time, of course, the reader will have gathered that the thing here described is of microscopic dimensions; and in fact its natural size (as will be seen by reference to the little figure to the left in our engraving) is no bigger than a pin's head, and presents no sign of organic structure to the unassisted vision. It seems to be simply a bit of dirty matter. Sometimes these creatures collect in such vast numbers as to form large masses of what looks like slime or filth, adhering to water-plants or pieces of decaying branches of trees, or

along the banks of our canals and ponds. That things are not always what they seem is here very forcibly illustrated. You take up a portion of this apparently dirty slimy mucous matter—say on the

FIG. 2.—*Charchesium polypinum.*

point of your walking-stick—and your first impulse is to throw it away in disgust. Put it again into the water, and it is seen to spread itself out in a less repulsive appearance. Take up a small portion again, put it in a small glass bottle of water, and peer at it through a pocket lens; it

begins to look attractive. You carry it home, and, placing a small bit with a drop of water in a glass trough or on a glass slide under a good microscope and with proper illumination, you behold a most charming picture. The repulsive bit of slime is transformed into trees and flowers, and all in active and beautiful motion. Here may be seen one with wide-spreading branches, with flowers and fruit, and, to all appearance, with birds sitting on its branches. Seeing as much as this, you would hardly be surprised if the birds opened their mouths to sing, and the fruit (like large oranges) dropped in its ripeness. What you do see is almost as strange, for the tree looks alarmed. You have, perhaps, touched the table or the microscope, and so produced a slight vibration which has thus reached the highly sensitive group before you; and down it sweeps, branches, flowers, fruit, birds, trunk, and all, in tiny contraction. You can only see now, even with good magnification, a very small dot of matter; but with returning quiet a slight movement is visible. It increases; the tree spreads out, and is all there again: nothing has been injured. This process is constantly repeated,

and is a very charming thing to see. The birds, of course, are an illusion; but on one of the species — *Zoothamnium arbuscula* — there is really fruit. It has all the appearance of fruit as seen on an ordinary tree, and it answers the same purpose as the vegetable fruit of the apple or orange. It is seed, from which new individuals and colonies are to be developed. As for the birds the writer has seen small and very pretty rotifers on the branches of this Zoothamnium looking so much like birds on a forest-tree that he could not help the comparison. Not that they are structurally like any known species of birds; but here one is, so to speak, in fairy-land. Before us a tree, contracting and expanding itself at pleasure; having flowers vibrating with active life — the corollas mounted with rotating discs, and visibly feeding on surrounding matter, with intelligent selection of the food required; and, perched on its branches, small and beautiful creatures that kept their places with the alternate contractions and expansions of the trunk and branches. Under these circumstances, there was nothing surprising in observing that those "birds" were crowned

with (apparently) revolving wheels instead of feathered heads with beaks, and clung to the branches with a fork-like foot, instead of having legs and claws.

It seems difficult to avoid using the words "tree" and "flower," &c., in connection with objects, though animal, which by their appearance naturally suggest them; and one is thus led to ask, whether there really is that great division in nature denominated by the words "animal" and "vegetable"? At any rate, whatever may be the case in the higher class of beings, this division fails us in the world of microscopic life, for not only by their forms, but more by their qualities do they deny us that division. They possess the attributes and faculties belonging to both the great kingdoms of Nature—animal and vegetable. Moreover, they fluctuate between the two, being at one time more animal and anon more vegetable, while at the same time combining the attributes of both in an ever-varying degree.

Thus a new kingdom has been suggested, to which the term *Protista* is given. It must not, however, be supposed that these remarks apply

in all their fulness to the particular family of creatures described in this chapter. The microscope alone reveals this new kingdom of nature, and we have here selected only one type of the strange life contained in it.

II.—REVOLVING ANIMALS.

"Thou man, who art the universe in little, cease for a moment from thy absorption in loss and gain: take one draught at the hand of him who presses creation's cup to thy lips, and so free thyself from the cares of this world and those about another."—(PERSIA) KEIJAM.

JUST within the border of Epping Forest, in the neighbourhood of Walthamstow, is a number of ponds and ditches in the fate of which some few naturalists are at the present time * nervously interested. It is reported that the City of London Corporation intend to drain and otherwise improve this neighbourhood; and as this may mean the obliteration of these precious ponds, the lovers of nature, or the special kind of that nature in this special district, are alarmed, and would fain draw off the drainage operations to other localities. As the

* The reader must remember that this was written in April, 1882, and was then also published in the *St. James's Gazette*.—ED.

ponds in question are not very pretty objects, the reason for this anxiety on the part of naturalists must be somewhat puzzling to the general public. I propose to enlighten them on this point by describing some of the rare forms of life that would thus be destroyed.

The *Conochilus volvox*, of which we print a

FIG. 3.—*Conochilus volvox.*

sketch, is only found in a very few favoured places, and that of the ponds referred to above is one of them. The winter is the best season for getting the creatures in their prime. I have always found them in best condition and in greatest abundance when the ice had to be broken to fish them up. The usual method for collecting these and similar

creatures is with a bottle screwed on to a ring at the end of a stick (collecting-sticks, made for the purpose, may be bought), and dipping here and there until you find what you seek. Having drawn up your bottle of water, you apply a pocket lens to the contents; and if you have caught the objects of your desire, you will see a number of small white rolling bodies, the *Conochilus volvox*. Not that all small white rolling objects are Conochilus.

These small white revolving objects, when placed under the microscope, appear marvellous and beautiful. We are all led to speculate sometimes upon the forms that life may assume in other worlds than ours. For those of us who are familiar with the use of the microscope these speculations and fancies are much widened: and I for one have come to the conclusion that nothing that could be found in any other world is likely to exceed in strangeness or beauty the actual forms of life which exist in countless millions in our own. Of these one of the most remarkable is the white rolling globe that may be gathered from the pond at Walthamstow.

First, bear in mind the size of the globe or the

white speck I speak of. A dot of the pen thus • will represent its natural size; and yet this dot is composed of about forty organised and complex animals, each one having a distinct individuality. The individuals of which this globe is composed are, as I have already remarked, of a somewhat complex organisation. There is the head with its crown of cilia, which by its vibrating motion resembles a wheel rotating on a pivot. This motion is common to most of this class of animals, and originated the name under which they are classified—namely, Rotatoria or, commonly, wheel-bearing animalcules. The rotatory motion is, of course, an optical illusion. It is like that of a field of corn set in motion by the wind; and if you imagine the wave-like motion thus produced to move in a circle, you will have before your mental vision the same appearance on a large scale as is produced by the Rotifers. By this motion a little vortex is created in the water around their heads and mouths, and down this tiny whirlpool their food is carried. They have each two eyes; manducatory, alimentary, and reproductive functions; also a suctorial foot by which they attach themselves to a common centre. This attach-

ment is very remarkable. No one has as yet observed the actual formation of the colony in this form from the commencement; but I have frequently seen the colony divide, and this is a most singular process. You have a fine group of, say, forty individuals under observation in a compressorium; and while you watch, separation takes place—not into individuals, but into groups; so that, instead of one globe of forty, you have two of twenty. No injury is done. It is as if an understanding had been arrived at that one half should go to the right and the other to the left; and the thing is done in an instant. There are eggs, and young ones are constantly being produced; so that the number of individuals forming any one group is not the same for any length of time: the number varying from ten to forty, and all attached to a common centre by their foot-like tail, which is furnished with a suctorial organ for the purpose. To keep the colony together, each member has to contribute something of vital importance. This is of a mucous or gelatinous nature, rather more dense at the centre than at the extremities, and it surrounds and keeps all together. This bond of union

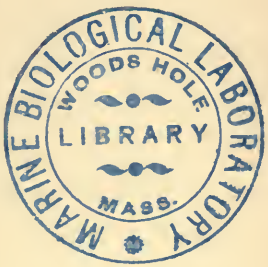
is very transparent; so that while it serves as a common shelter within which each individual can retreat at will at the approach of danger, it does not obstruct the view of the beholder. When kept for any time beyond an hour or two under observation in a contracted space and in a warm atmosphere, this gelatinous envelope becomes soft; and the individuals forming the colony, no longer held closely and firmly together, slip out one by one, stray about helplessly, and soon perish. This probably is the reason why these creatures flourish best in cold weather. In some instances the mucous investment of the Conochilus is green, or partially so, and is probably caused by the nature of the food on which they have been feeding; and this beautiful gauzy transparent green membraneous matter enveloping the white crystalline rotating colony, adds greatly to its beauty.

Before this strange little colony breaks up, let us note it more particularly. Remark that each member is furnished with an apparently revolving or rotating wheel-like head—in fact, a wreath of cilia which, lashing the water from nearly all points at once, produces a whirl or vortex. The

whole group doing this together, and almost incessantly, causes it to roll over and over; so producing the appearance of a sphere of transparent and beautiful creatures, each one revolving on its own account, and the whole revolving together in perfect harmony. There is but one known species of these creatures, and they are not found everywhere. But they are found in abundance, tens of thousands of them together sometimes, in these Walthamstow ponds. Can we then wonder that there should be some anxiety lest one of their well-known and easily accessible habitats should be destroyed!

The microscopist dealing with things invisible to ordinary vision, and consequently with forms of matter with which the general public are unacquainted, labours under some disadvantage, appearing to attach too much importance to such *minute* objects; but a little consideration will surely dispel all such notions. The investigations of science within the last few years have made it apparent that our own welfare—physical, mental, and commercial — depends considerably on the comparatively small and invisible forms of life with which

our lives are environed on this earth; while the great globe itself owes no small portion of its form, beauty, and fertility to the united labours of the countless millions of its infinitesimal inhabitants.



III.—THE BRICK-MAKER.

"Though lowly here our lot may be,
High work have we to do."—GASKILL.

"There is no great and no small
To the soul that maketh all."—EMERSON.

THE *Melicerta ringens* is an animal so small that, although it lives in a brick-built house or castle of great beauty and strength, one might swallow a score of them in a mouthful of water, houses and animals altogether, without noticing them; and therefore to ascribe intelligence to an animal so small seems at first sight rather preposterous. Small and great, however, are only relative terms; and in the region of microscopic life, this creature is rather a large one as compared with thousands of others—as large, indeed, as an elephant is to a mouse in the visible creation. Thus regarded, the objection as to size vanishes.

The vignette represents a group of these very

interesting animals in their dwellings; or, rather, they are partially showing themselves from the one opening on the top. They are rarely found in a social condition as here shown, generally preferring a detached residence. In this instance quite a

Fig. 4.—A Group of Melicertans.

group have collected, and built their habitations around and on the parental structure. The young are developed from eggs, which are laid and hatched within the tower-like house. Owing to the peculiar structure of its inhabitant, great care is required in this process. The egg is shot forth near the top of the tower and caught within it, falling gently

alongside the animal to the bottom, where it is hatched, and the young protected until they quit the parental abode, to which they never return. A young Melicertan is a very different creature from its parent, having two eyes, and swimming rapidly from place to place. This is the period of youth; free and easy, it travels over its little world. Soon, however, it gets tired of this roving life, and selects some congenial spot on which to build a house, and, having attached itself—or literally put its foot down—never removes. It is generally some filament of algæ or other water-plant to which this attachment is made; but in the instance before us, as we have seen, the parental dwelling is chosen. The eyes now disappear from ordinary view, being changed from the prominent eye-spot character hitherto presented into exquisitely fine crystalline ruby-like points. In this condition, and being, moreover, liable to be enfolded in the large trochal organ which is now developed, they are not easily or often seen, and the general inference is that they have disappeared altogether.

This, however, is a mistake, as I have often

demonstrated their presence. Moreover, the idea suggested by their presumed disappearance, that because the creature no longer leads a rambling life, that therefore it no longer requires organs of vision, is out of harmony with all natural analogy, and especially so with the animal before us. Our further observations place it among those beings on whom nature has bestowed complexity of structure, and relatively high capacities for both use and enjoyment.

And first, let us remember, our tiny acquaintance is naked and homeless. Nature, however, is kind, and has furnished it with a ready-made brick-making machine; which, being part of its own organisation, is ready for immediate use and is not likely to get out of order. Perched on the leaf of a plant, the machinery is set in motion: a transparent flower-like crown, having four lobes, is gradually expanded. This is fringed with a double row of cilia, which produces a motion of exquisite beauty. It is of a rotary character; and so, by producing a corresponding motion in the surrounding water, any inorganic matter therein floating is drawn into the vortex, is caught up by the

expanded leaflets, and carried round between the double row of cilia towards the mouth. Here an important operation has to be performed. The material collected is not all fit or required for food, and consequently a sorting or selection is made before it is admitted: some is sent down to the gizzard, there to be more finely triturated and passed on as food; other is taken into the pug-mill, as the brick-making machine is often called; and the remainder rejected as worthless. There is no stoppage of any one operation for the performance of another: collecting, sorting, grinding, and brick-making are all going on simultaneously. You have before you a beautiful piece of machinery, and hardly know which part of it to admire the most. Let us for a few minutes watch the brick-making operation. We see a few grains of matter spinning round, which every moment is growing denser, acquiring consistency and a rounded or conical form. In three minutes it is finished and deposited on the outside, where a film of gelatinous matter is already waiting to receive it. Thus the first brick is formed. Others follow in due course; and soon a ring of them is formed round the middle of the animal:

pellet by pellet and ring on ring is added, and gently and gradually pushed down until the basement is reached to which the architect is fixed. To this basement the building is firmly cemented; and the house may now be said to be constructed, and only requires additional rings of bricks in proportion as its occupant grows and requires more room for shelter and repose.

Pondering over the selective character of the "sorting" operation above referred to, one feels that it can be due only to intelligent perception of the difference between one kind of matter and another; and this conviction is confirmed by the following observation. A loose mass of effete matter is thrown forth with more than ordinary force, and in the usual habitat of the creature—in a pond—would speedily be carried away. But here, in the contracted space of a small glass trough, it is repeatedly brought back within the little whirlpool created by the ciliary action of the trochal disc, and we expect every moment to see it carried down the vortex to the stomach along with its food. But not so, it is not even admitted to the sorting apparatus before described, but is at once and

peremptorily rejected, and thrust back again and again with increasing force, as often as it comes within the ciliary current.

Now in reference to much of the motion previously observed, it may be conjectured to be independent of the will, but in this instance exceptional conditions are imposed to which the creature responds by as intelligent action as it is possible to conceive. Nor, considering the complexity of its organisation and its relative rank in the scale of invisible life, is there so much improbability in the fact of its intelligence as at first might appear. But it is not intelligence alone, or even principally, which enchains the attention; this may be equally shared by other minute beings: it is the extraordinary beauty and mechanical contrivances which renders it so general a favourite. Moreover, it lives and thrives well in confinement, and has no objection to some interesting experiments—making and building with coloured bricks, for example, if we give it the colouring matter.

Let us take another look before leaving. Touch the table or the microscope a little roughly, and danger is apprehended by the Melicertan: quick as

thought it retires within its stronghold. But if now we wait and watch we shall perceive two fine projecting points, tipped with fine setæ or bristles: these are feelers or antennæ, and give the required information as to danger. When satisfied as to its security, it prepares to come out and resume work: there is a gentle trembling and quivering around the bulwarks; the head is thrust out and again withdrawn, as if in doubt of safety. Finally assured, the flower-like trochal disc is gently expanded and unfolded.

There is another Melicertan which merits mention, although it has been named "Tyro," by comparison with its more exalted neighbour. The reason of this designation being that while the creature is furnished with the ciliated cup, *i.e.*, pug-mill or brick-making machine, it yet does not make any bricks at all. The organisation and material are both supplied, yet no result appears. This is not the usual method of nature's working in the ascending or progressive scale of development, and the disuse of this organ must be rather regarded either as indicating reversion or retrogression, than an attempt to reach the level of *M. ringens,* which

the word "Tyro" suggests; as its disuse may be ascribed to an advance in organisation in another direction, or an environment which rendered it no longer necessary; or even it may be the result of accident in some remote ancestor, who nevertheless managed to live and perpetuate the injury to its descendants.

Instead of making bricks and building a home, *M. tyro* secretes a glutinous covering, in which it moves and has its being. This is of rather a loose texture, and may be regarded as approaching the Limnias, described in our next, or to that of the Floscules in No. V. To return, "*Melicerta tyro* is a Melicertan with a gelatinous sheath very like that which invests the Floscules, and yet with a distinct character of its own." Its trochal disc is four-lobed like that of *M. ringens*, but with more of a "butterfly" character when expanded, and having two long antennæ. Moreover, the eyes even in the adult form are more readily seen than in *M. ringens*, or the Floscules. All things considered, it does not seem to be undergoing a process of deterioration, notwithstanding the loss of its brick-making faculties.

IV.—TUBE-DWELLING ROTIFERS.

"At the foundation of all organisation there is an original intrinsic kinship."—GOETHE.

"In truth, nature has no such fancies as those man is ever ready to credit her with. She has but one law—endless variety; and her varieties blend into one another by such fine gradations that no natural system of classification can be other than unsatisfactory, doomed to be destroyed and re-cast by each succeeding generation of naturalists."—C. T. HUDSON.

ALL careful observers are familiar with the gradations in the scale of life: every class, whether animal or vegetable, presenting such differences in organisation and habit as indicate a gradual progression towards perfection, with occasional relapses, or retrogression.

In *Melicerta ringens* (described in No. III.) we have the highest this form has reached; and between that and the lowest, are several grades approaching more or less closely to perfection. There is *M. pilula*, for example, which is at once observed to be lower in the scale by the striking

contrast between its dwelling and that of its near relation *M. ringens*. Without going into details of structure, one observes that it has only a two-lobed trochal disc, or crown (which, however, is very beautiful), and that, although furnished with a cup-

FIG. 5.—*Limnias ceratophylli.*

like organ, or pug-mill, yet it does not make bricks like *M. ringens:* this cup-organ only secreting a gelatinous fluid, with which the creature invests itself, and on which it drops or throws pellets of mud or rather excrement. These, sticking to the viscid secretion, gradually, and without any symmetry, form a covering or refuge. So that while the

former gets a mansion built with mathematical precision, on a symmetrical plan, from materials carefully selected, the latter gets only a mud-hovel formed, or thrown loosely together. While the one structure is strong and enduring, forming a monument of stability even when uninhabited, the other is always falling "about the ears," so to speak, of its possessor.

Between these two extremes are several others, of varying perfection in structure and capacity.

Our illustration shows a group of *Limnias ceratophylli*, the "two-lipped tube-wheel of the *Hornwort*." The *Ceratophyllum demersum*—or Hornwort, as it is commonly called—is its favourite resort, and has originated the specific name of the creature; but it is by no means specific of its habitat, for the animal will attach itself to almost any water-plant, and is found in great abundance in the canals about London.

Somewhat resembling the Melicertans, *Limnias* yet presents many differences, the most noticeable being the form of the flower-like wheel and the structure of the tube-like dwelling. But while *M. ringens* builds with bricks, and *M. pilula* with pills

or pellets, *Limnias* constructs its house with thick gelatine of rather a horny consistency; and being at first soft, it forms good material for the attachment of foreign bodies and the young ones who may chance to light upon it; for these, like the young Melicertans, are at first free-swimming, and have two eyes, which they appear to have lost on arriving at maturity and a fixed abode.

The wheel-like organ consists of two nearly circular lobes, or lips, fringed with cilia, showing all the appearance of rotation as each wave of cilia follows its fellow round the course, thus producing a picture of great beauty to the beholder. This ciliary motion, or some modification of it, is almost universal in all microscopic animals—as it is also in some of the tissues of the higher forms of life—and is the method by which nourishment is collected, and in some cases locomotion achieved. We see then, the food collected by the ciliated flower-like lips, and passing between them, down the buccal funnel, through the æsophagus, or gullet, to the manducatory bulb, or mastax; which latter consists of jaws furnished with strong teeth, working on each other, tearing and grinding the smaller

animals and other organic materials collected from the surrounding water.

It seems almost like drawing on the imagination to speak of *jaws and strong teeth*, &c., &c., in creatures so small as to be only just discernible with the aid of a pocket-lens. Yet it is no fancy sketch; nay, more, the organs of which we speak are not only clearly distinguishable with the aid of the microscope; but some of them, such as the mastax of *M. ringens*, with its jaws and teeth, have been dissected out and mounted on glass as separate objects of interest.

This mastax is a prominent feature in all the *Rotifera*, and at once attracts the observer's attention. It consists of three well-developed lobes, or masses of muscle, two of which, with the teeth, are seen to be working against each other, grinding down the food on to the third, which forms a sort of table. The food thus finely triturated is now passed on to the digesting stomach or alimentary canal, which is divided into several compartments, each furnished with its appropriate secretions for converting the food into the tissues of the animal body, &c. In fact, all, or nearly all, the organs

of the higher class of animals are here found in miniature, so small and delicate, and yet so effective as to excite our highest admiration and wonder. Are not the facts of nature stranger than any imaginable fiction?

To return to the illustration on page 28, it is seen that a number of individuals are grouped together, the central one being probably the founder of the colony. Sometimes twenty individuals will thus attach themselves; but their doing so is not habitual: it is simply a matter of choice or accident. As before observed, when young they swim about in freedom: but not for long; as a firm and permanent support becomes necessary. Looked at in a glass trough under the microscope, they are seen to try several positions—sometimes the glass sides of the trough—before finally deciding where to settle. When, however, this is done, they remain; and developing, as we have seen, the prime materials for a habitation from their own bodies, work out their little destiny. The tube or dwelling thus formed is about one-fiftieth of an inch in length, at first semi-transparent, but becoming brown with age and the ad-

hesion thereto of foreign matter. When completed it is cemented to a firm support, and is no part or attachment of the body of its maker.

This grouping or association into colonies, both of these and other organisms, is very suggestive. The tendency is more or less developed in proportion to the strength or weakness of the individual, and the peculiarities of its environment. Some forms of life there are of a much humbler character than those now under consideration, which yet are solitary in their habits ; it will, however, be found, on close examination, that they are furnished with some subtle means, both of offence and defence, which is often more than a match for those of much higher organisation in the struggle for existence.

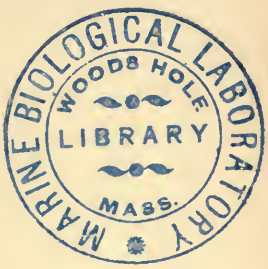
Confining our attention for the present to the *Limnias* and its relatives, we find it very interesting to observe the various methods adopted in these associations. Thus the *Conochilus* shelters all its members in one common protecting substance which envelopes the whole family circle. The *Limnias*, on the other hand, preserves its individuality, while yet combining with its neighbours in grouping

their dwellings together, and so offers greater resistance to any sharp-eyed and rapacious strangers—of which there are many—who may be disposed to gobble them up. The former is the "family," the latter the "social" life.

Closely allied to *Limnias* are *Œcistes*, *Cephalosiphon*, and others—all *tube dwellers*—and bearing a strong family likeness to each other. The difference between *Limnias* and *Œcistes* consists principally in the character of the rotary organ, which in the former is *bi*-lobed, and *single* in the latter; while in *Cephalosiphon* there is an additional attraction in a curious syphon-like projection, the use of which seems to correspond to the antennæ of insects—as a projecting feeler after information for the benefit of its proprietor.

There is yet another tube-dweller which must not escape our notice. It is described in the "R. M. S. Journal" for December, 1878, as a new form, and obtained the name *Œcistes umbella*, from the peculiar *umbrella-like* form and structure of its circular disc or head. There are the ribs and covering, and when fully expanded or partially folded up, the resemblance, as far as the upper

part is concerned, is very striking. Of course the handle—or what is here the body—of this beautiful creature is very different to that of an umbrella, and is furnished with all the usual alimentary and other organs essential to its well-being.



V.—CRYSTALLINE VASES AND THEIR INHABITANTS.

"If we consider plants and animals in their most imperfect condition, they can scarcely be distinguished. But this much we can say, that the creatures which by degrees emerge as plants and animals out of a common phase arrive at perfection in two opposite directions; the plant in its highest glory reaches the tree; the animal, in man."—GOETHE.

WHY or how it has come to pass that Nature puts on such a variety of forms is rather a puzzling question, especially so to those who insist on separate creations for every one of them. If, however, instead of starting in our investigations with a preconceived theory, we simply examine and note the facts of natural history, we are charmed with this infinite variety, and are under no temptation to twist and distort what we see to make it fit into any theory. The great drawback is the almost bewildering classifications and terrible names which,

under the specious show of great learning, are now presented to us. These things are at last in such a muddle that they are more difficult to master than the objects they are designed to teach; and, indeed, if one would really learn as much as

FIG. 6.—*Floscularia campanulata.*

possible of the operations of Nature, he must leave those devices of man to come in after, and not at the commencement of, his studies. He must go to Dame Nature's own school, and little by little learn all about her, even as a child learns to walk and talk.

Pursuing this method, we eventually find that organic life on this earth is not split up into sharp and well-defined classes as at first sight might be

supposed. Underneath the appearances is seen the one continuous stream of life, modified by its environment, and branching off in various courses, more or less complex according to the obstacles to be overcome, but always preserving its own essential character. This being so, while similarities must appear in the several branches, one is not surprised at not finding any sharp dividing lines, and is not disposed to wrangle over classifications which do not exist in nature. The substance or the matter of life is found to be plastic, and hence variable; intelligent, and therefore adapting itself to its environment; is progressive—ever aiming at the highest possibilities of existence. All its many phases are seen to be the natural outcome of these its main characteristics, from the simple bit of plastic matter we name the *Amœba*, up to man himself.

To come to the main object of this paper. The almost invisible forms of life are operated on by the same causes as the larger and more complex organisms; and the reason why a Melicertan builds a house is the same as that which develops a thorny covering for the hedgehog. Self-preservation is the first object to be secured; and the varying devices

resorted to for accomplishing this end are dictated by surrounding circumstances, though we cannot always trace them.

The Floscularia comprise several varieties or species; but this one, a group of which are here sketched, is the *Floscularia campanulata*—the flat-leaved Floscule or flower. Actual flowers, being visible, got their names before those little creatures which so much resemble them, and which are thus in so many instances named after them. This one has five petals or lobes constituting its head. On the angle of each petal is a tuft of setæ, or bristles, very long and fine, and which when expanded fall in a "graceful shower" around the body of the animal. Although classed among the Rotifera, it yet has no rotating organisation; but a faint line of cilia inside the lobes and along the mouth produce a current in the surrounding water towards the opening, carrying with it the food required. This food is of both animal and vegetable nature, mostly small infusoria and motile plants, which in its transparent body gives it at times the appearance of a crystal goblet full of jewels. Of the general varieties of Floscules, *F. ornata* is perhaps the

most beautiful. Its crystalline dwelling is finer and its movements more graceful than the others. Why *F. campanulata* is here sketched in preference is because of the exceptional character of the group. They are solitary in their habits as a rule; but here seven individuals (only six are drawn) were found attached to the stem of a water-plant so gracefully arranged, forming a most delightful picture. Instances of this character are often found in nature; where separate individuals, as if following the law which by its predominance has made them individually beautiful, combine to form another beautiful object, just as a little child may collect a bunch of wild flowers and arrange them in a pleasing nosegay, or join hand-in-hand with companions in a dance on the village green. These natural groupings of beauty are very instructive, as showing the almost universal tendency in this beneficent direction of all animate and inanimate things alike. They form the pictures which the artist loves, and which he will travel miles to see and immortalise on his canvas, and the microscopist sit long into the "stilly night" beholding with wondering and enchanted vision.

The Floscule is developed from an egg, and when young, like some others we have described, has two red eyes and is free to roam about as it likes.* After a time it attaches itself generally to some plant and develops its habitation. This consists of a gelatinous secretion, very transparent, and is formed into a cylinder or tube around its body, in which it lives. One is not impressed with a sense of its security, as is the case with *M. ringens*, so much as with its beauty. Its dwelling being transparent, all its charms are seen, and the wonder is that it escapes its enemies. One arrangement, however, is very curious, as being apparently designed for protection. When the Floscule retires within the vase, the flower-like crown with the five or six bunches of long bristles is folded over transversely ; but the bristles, being so long and thus drawn together, form a projecting broom-like appendage, rather formidable to any would-be intruder. Now, the vase being so transparent, this arrangement, if intended for protection,

* The eyes, both in Floscule and Stephanoceros, are generally supposed to exist only in the young. This is an error, for I have repeatedly demonstrated by experiment their existence in the adult forms.

is somewhat like that of the ostrich hiding its head in the sand while its body is uncovered and visible. At any rate, it has managed to live and thrive, though not so abundant as some of its better-defended relatives.

Not much has been said as to the beauty of this creature: in words it is difficult to describe this striking feature. Imagine if you will, a lovely flower-like animal within a fine crystalline goblet; it is folded up for the moment, but its life is too short for long repose, and soon it proceeds to resume its normal state. The petals open, expand, and the finely spun glass-like setæ, finer than the finest hair you ever saw, are thrown forth in flowing flossy masses, glistening in the light with opaline tints, and, spreading out in all directions beyond our utmost gaze, all in wavy lines around the body of its possessor. Such is the beautiful Floscule.

But the crown of all the Floscularia, the one that stands alone in majesty of form, is the Stephanoceros, a sketch of which we print. We have no varieties here, at least none sufficient to constitute another species; and this fact harmonizes well with its unique character and position as the "head of the family" of the Floscularia.

All through nature one finds examples of this kind, where one branch or rivulet of the great stream of life culminates at a point of perfection beyond which it cannot go : such is the *Stephanoceros eichhornii*. We take this creature out of its native

FIG. 7.—*Stephanoceros.*

ditch or pond, where it is found attached to a branch of a water-plant—say, on one of the spiked leaves of the hornwort (from which it depends in graceful beauty)—and placing it in a small glass trough under the microscope, with a paraboloid or dark-ground illumination, proceed to examine it in detail. If we have a fine specimen it is impossible not to stop to admire the elegance and

beauty of the creature under our gaze. We may have seen it hundreds of times before, but its attractions never pall. It stands up so erect in its crystalline tower, with its five arms either expanded or folded up in an undeniable kind of majestic elegance. Along the arms are seen numbers of *verticils* of long and vibrating cilia. Ever and anon a nervous thrill seems to pass along these arms, and the cilia flash out as if charged with an electric current; and presently a small animal, that has for some time been hovering about the Stephanoceros, descends between its arms and through the wide gullet to its final destiny as food. Concentrating our attention, we observe what seems an egg within the transparent body of the Stephanoceros; and, increasing the magnifying power, we can now distinguish the small embryo folded up, and its two bright ruby eyes—shining points of the finest imaginable character. Now the egg is developed or laid, and remains close up to the body of the parent within the dwelling. Here the very delicate incipient life is securely protected and provided for, and we sit hour by hour to watch the intensely interesting operation of its unfolding. The egg

does not burst; the little life within does not break its way out. It is literally an *unfolding*. It is as a flower unfolds: one by one, its several parts come into view, spread out and take up their functions. Now the cilia move, the creature rolls over, its eyes brighten, it elongates, its head appears crowned with cilia, it straightens out its entire body. The Stephanoceros is born, or hatched. What before appeared as the egg-covering is now seen to be the external skin of the animal, within which its embryonic life lay folded up, and in which it is now developed and protected. The exquisitely delicate organism thus developed is still further protected and provided for, until strong enough to care for itself, by the casing in which it now finds itself. This dwelling is of transparent jelly, secreted and formed in ring-like folds. When young and in good condition it is more transparent than the finest glass; gradually it hardens, and is strengthened by those folds which act as stays and foundations for the superstructure as tier after tier is formed. Sometimes the base is extraordinarily strong; and the whole structure resembles a fine crystal vase, the upper portion being transparent and the lower slightly

opaque and of a more solid and substantial character.

It has been a subject of much dispute whether this tower or case is solid or cylindrical. The truth is that when young it is perfectly cylindrical, with those curved indentations or folds as stays or supports; and it may remain so under favourable conditions for a long time. However, as often as offspring are produced, so often is there an extra secretion of jelly; and this sometimes fills up the tube so much as to leave only room enough for the animal to move up and down, and the young have to eat their way right through it to get out. These remarks lead us back to the young and but just newly-hatched Stephanoceros. Finding itself surrounded by this cylindrical structure, it exerts itself to get out; and, gradually making its way upwards, swims gently out near the top, where the gelatinous folds are so very thin and flexible that no rupture appears to have been made by its exit.

No one would recognize this now roving little creature as a Stephanoceros who had not seen it hatched or known it previously; and it passes through another stage before finally appearing in

its perfected form. When young and free there is no sign of those five long and beautiful arms, or lobes, which are the chief beauty and characteristic feature of its mature condition. It has simply a tuft of bristles on its head, two ruby eyes, and a vermiform body; and in this form it passes the time of youth. Now it is weary; life seems ebbing away; and so, resting on any support in its way, it appears to fall into a state of coma, or death-like repose, during which the wonders of its perfect nature are being matured, and from which this minute organism emerges to vigorous life.

VI.—REVOLVING PLANTS.

"The rounded world is fair to see,
Nine times folded in mystery;
Though baffled ears cannot impart
The secret of its labouring heart,
Throb thine with Nature's throbbing brea
And all is clear from east to west;
Spirit that lurks each form within
Beckons to spirit of its kin;
Self-kindled every atom glows
And hints the future which it shows."—EMERSON.

THE *Volvox globator* here sketched is a very small and beautiful plant. To those unacquainted with the revelations of the microscope, this statement will appear rather startling, so different is this organism from what are usually known as plants. The fact is that we are here again on the border-land or debateable ground between vegetable and animal life; and although the botanists have established their claim to the *Volvocineæ*, there being more of the vegetable than of the animal in them, yet the posi-

tion in classification of all such beings, whether partaking more of the characteristics of one kingdom of nature than of the other, is not considered quite satisfactory; and some eminent naturalists propose the establishment of an intermediate king-

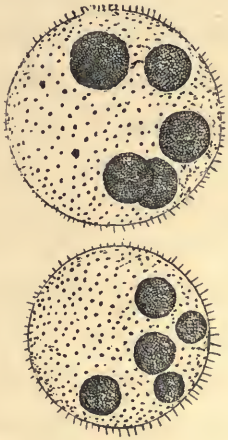


FIG. 8.—*Volvox globator.*

dom, in which those intensely interesting, and other forms of life, should be included. While, however, the naturalists are disputing, let us examine the wonderful forms before us. They are, as their name implies, revolving globes; each sphere containing within it a number of other similar, but only partially developed, smaller spheres or globes.

The whole compound organism, rolling and revolving in the water, forms a picture which once seen is never forgotten.

We call them plants, for they are mostly green, and have but few of the characteristics of animal life. "Yet," you say, "they move." Yes, they are motile plants; and if examined a little more closely, are seen to be covered with fine cilia, or hairs, which by their vibrating action are supposed to be the cause of the revolving motion observable. We have probably here a prominent instance of the active agency of sunlight on the vegetable world. These special forms not being attached to the earth, or, indeed, to anything whatever, but only suspended, as it were, in a medium which by its elasticity does not offer sufficient resistance to keep it in one position—and this aided by the peculiar globular form of the plant and its hair-like appendages—the sunlight, which in other fixed and stable forms produces an expansion of growth, is here partially expended in producing this revolving motion.

It is a matter of common observation that all vegetable life seeks the light or is attracted by it.

Now, if a number of these *volvoces* be placed in a glass jar, they will sink to the bottom when in darkness, but in the light will all arise and congregate together against the side where there is most light. Place the jar in the sunlight and they will move to, and revolve rapidly on, the bright side. The motion of these bodies thus appears to be due to a combination of causes—the globular form, the vibratile cilia, and the sun.

The cilia here referred to is a matter of great interest, and worthy of attentive study. Let us try to understand it. Looking now at one of those globes under slight pressure, so as to keep it in one place, and with a high magnifying power, we see that the entire surface of the sphere is covered with a network of cells, each cell being hexagonal (produced by mutual pressure) in form, and each one attached to its neighbour by a very fine thread which runs straight across from cell to cell. The attachment is not at the angles, or by the sides of the hexagons, but by the delicate threads which cross the interspaces between. The whole membrane of the globe is thus seen to be so many distinct cells, held together by this thread-like attachment. As

the globe grows and expands, those threads are stretched to their utmost limit, and finally a breach is made in the membrane; and thus the now matured inside globes make their escape or exit, and commence an independent existence, repeating in their life-history that of the parent form. From the centre of each hexagon are produced two fine filaments, or cilia, which, being projected on the exterior surface and set in motion, cause the globe to revolve on its own axis. It should be noted that these threads, or cilia, are simple extensions of protoplasm, or living matter, which is either moving or lying quiescent, in accordance with the requirements of its environment.

The hexagonal cells are the source whence new spheres are formed; but only a few in each sphere are selected for this purpose, and those beginning first to show certain slight differences—such as flattening out—are readily distinguished from their surrounding neighbours, and their subsequent development traced. Soon this flattened cell is seen to double, but not actually to divide or separate; next this double cell is multiplied, and we have a group of four. These are now separated from the original

cell-wall and lodged in the general cavity, where they continue to multiply in this geometrical ratio; and, joined by others similarly conditioned, now develop the fine cilia and revolve within the original revolving parental sphere. Not only so, but another generation is generally commenced within these, before the ever-expanding outer sphere bursts or is gently opened.

We have thus in each plant, globe within globe revolving; and when you get a number together—pure green and transparent—each one revolving in its own orbit and carrying similar revolving globes within themselves, and the whole moving without confusion or collision gracefully through the still, clear water, you have almost a miniature of the solar system under your gaze. If you have a vein for poetry, the contemplation of the hidden beauty of this little plant, thus revealed to your senses, is enough to awaken it. But this is not all; within those globes are often seen veritable live animals—small rotifers, each one having a complex organisation. They are free-swimming creatures; and as they move through the hollow sphere of the Volvox you can trace their mode of life, &c. I have often

seen half-a-dozen within one Volvox sphere, and watched their depredations—for, however they may get there, there they are, and must eat to live; and so the young, half-developed Volvoces become their prey, and the whole globe is sometimes spoiled and rendered unproductive by these little parasitic depredators.

During the summer the *Volvox globator* continues to propagate, as above described, by self-division or multiplication; but by the autumn two new kinds of cells make their appearance within the parent globe. These are larger than the ordinary ones, and do not divide—or, rather, only one of them does: and this is in a totally dissimilar manner to the usual plan. The new cell thus referred to is the male or sperm cell, which, instead of dividing into globes, simply develops itself into flat discs, and, losing the green matter, is transformed into red or yellow, and eventually appears as an elongated cell, with a red eye-spot and two long cilia. The other of the new cells is the female or germ cell, and does not divide. It is at first pear-shaped, but finally becomes globular and enveloped in a glutinous membrane. As this operation becomes perfected, the sperm cells

break up into a number of antherozoids, as they are now named. These are free and rapidly swimming animal-like bodies, and assembling round the globular gynogoinidia, or germ cells, penetrate the soft gelatinous envelope, and coalesce or are absorbed in them. Thus is formed the winter cell, or egg, which sinking to the bottom of the water, and remaining in this condition during its hibernation, is destined to become the progenitor of another generation. In the spring this egg or spore becomes swollen, breaks, and the contents, consisting of small cells, are projected into the water. Here they soon begin a geometrical method of propagation—dividing first into two, then four, eight, and sixteen combined bright-green cells, each with its two filaments of active cilia. So is formed the new plant, destined to repeat in its own history all the interesting phenomena of its ancestors, as already described.

There is yet another phase in the history of this interesting organism. At certain stages some cells lose their vegetable character altogether, and become animals, closely resembling *Amœbæ*—a little bit of formless protoplasm, moving hither and thither by throwing out prolongations, or limb-like projec-

tions of its body, in whichever direction it chooses to take.

No merely written account can adequately convey to the mind the exquisite beauty and graceful motion of these pure green symmetrical and translucent spheres. They are sometimes found in great abundance in rather shallow ponds and ditches, and are always objects of great interest to the beholder, especially when it is considered that all the phenomena here described (and much more) are included in an organism just discernible by the keenest vision unassisted by the microscope.

VII.—LIVING MATTER.

"The addition of matter from year to year arrives at last at the most complex forms; and yet so poor is Nature with all her craft that from the beginning to the end of the universe, she has only one stuff—but one stuff with its two ends to serve up all her dream-like variety."—EMERSON.

THERE are simpler forms of life than even the Amœba, but few more curious and interesting. If some pond-water is put into a bottle and allowed to settle, the object we are in search of will probably be found in the sediment at the bottom. A drop of this should be gradually allowed to fall from a dipping-tube on a glass slide, and then, being covered with a thin glass cover, placed on the stage of the microscope for examination. If we are fortunate, we shall see a very fine bit of almost clear, jelly-like matter, of irregular outline; and on observing it attentively for some time, we shall remark a withdrawal of some portion of its jagged

form, and a projection of others in different directions. At first sight you would think the little organism under your gaze had burst. But you are soon convinced that this is not so, as a similar motion is seen going inwards; and by its expansion in one

FIG. 9.—*Amœbæ.*

direction and contraction in another the whole mass, or animal, is moved forward. This is its method of locomotion. These projections of its substance are named *pseudopodia*, or false feet, which, however, are more like gloved fingers than feet. Yet, such as they are, they are extemporised as often as required—now in one direction and now

in another. Although the actual form of these projections does not differ very much, yet, by their appearing at different places, they cause the whole body to change its shape so constantly as to gain for it the name of the *Proteus animalcule.* By this method of projection it not only moves from place to place, but also takes up the food it requires. We may say truly that it makes a foot or a hand as often as it requires either, whether to feed or move. As to its feeding, you will see one of these finger-like processes come in contact with something suitable to its sustenance; when it will quietly roll over it, and so [absorb or draw it into its own substance and digest it. It also sometimes —undesignedly—multiplies itself by this means. Thus a finger or a lobe is thrown out too far for its owner to draw it back again. In this condition the lobe acquires a thickening and widening at its extreme end; and the effort of the parent body to draw it in produces such an attenuation of its intermediate substance that it ends by being detached from it altogether, and so a new Amœba is formed. As a rule, however, this process of multiplication by fission or self-division, so common in

all the lower forms of life, is performed in a regular and methodical manner. In order clearly to understand this process, another very simple yet important part of the structure of the Amœba must be observed. This is seen in the sketch as a mere dark spot. It is the *nucleus*. Within it, is also seen another small dot named the *nucleolus*. These are the germs of future generations. The power and potentiality of life is stored carefully here; and consequently when a division is to take place a portion of this important matter must go along with each half. When fission is about to occur, a constriction, slight at first, is seen going on on each side of the main body of the Amœba, which gradually increasing, at length embraces the nucleus; the nucleus then divides, giving half of its contents to each part, and resuming in each its perfect form and function. The appearance now presented is that of two Amœbæ, just linked together by an ever-lessening tie; and this finally parting asunder, the two forms pursue (each one for itself) its own independent existence. This is the usual method. Another has been observed when a gelatinous cyst is formed, enclosing the whole

body, and swarm spores are seen to issue from the nucleus.

There is another part of the structure of this curious creature which must be noted, as it is probably very important, though its exact function, as observed in this and other similar forms of life, has not been as yet exactly determined. A little white speck is seen in the woodcut of about the same size as the dark one. This is the contractile vesicle; and it is very curious to see how it, as it were, opens and shuts. The opening or expanding motion is very slow: a little clear space is seen, which gradually enlarges until, attaining its maximum, it begins to fade away, and suddenly collapses or shuts up as if with a spring. In a moment or two it begins to open again, and so on, expanding and contracting. This is probably a respiratory or circulatory motion of a very rudimentary character, and perhaps is to keep up the proper supply of oxygen required by the animal.

The only other thing about the Amœba that can be called structure is the membrane which envelops its whole body, and which is so thin and transparent that the microscope fails to reveal it, and its

presence therefore is ascertained only by chemical re-agents. The Amœba, consequently, is not all pure protoplasm, and must take its rank among organic structures: it approaches the dignified position of a true cell, and is fairly on its way to higher grades in the animal creation. In fact, it has already reached a higher grade; for here are true *Amœbæ* (*Arcella* and *Difflugia*) enclosed in something more than an *invisible* membrane. These have something so dense to protect them that it may be called a shell.

Arcella and *Difflugia* are testaceous *Amœbæ;* the former having a horny covering, and the latter an envelope made of particles of sand, shell, and so forth, cemented into a sort of pitcher open at one end, whence the "filmy fingers" of its inhabitant protrude in search of food. The home of the *Arcella* is egg-shaped, and delicately marked with a minute and regular pattern. We thus approach one of the most wonderful operations of nature, and one which is still involved in much obscurity—namely, the formation of shells, or rather the marvellous form, markings, patterns, and appropriate colours which are produced under this name. Curiously enough,

within certain limits, the more simple the organism the more beautiful is its shell or shield.

Any description of these creatures is hardly complete without some reference to their size. The naked *Amœbæ* figured at the head of this paper range from $\frac{1}{3000}$th to $\frac{1}{700}$th of an inch in diameter, and are of such extreme tenuity that they are not in the least incommoded by being placed in a compressorium—that is, pressed between two thin pieces of glass with a drop of water, in which they move with perfect freedom.

VIII.—ANIMATED TRUMPETS, HATS, AND PURSES.

"Where the pool
Stands, mantled o'er with green, invisible
Amid the floating verdure millions stray."—THOMSON.

THE *Stentores* are among the most prominent forms of Infusorial life. They are of various forms, sizes, and colour; and few objects are more beautiful and attractive to the amateur microscopist. They are, moreover, easily found and recognised, and once seen are never forgotten.

The sketch represents a group of Stentors, green and white. When expanded they are trumpet-shaped, very much like the old "post-horn" of former times—the expanded end of which will represent the head of the Stentor and the remainder its tapering body. This thinning-out of the body is very singular, for it is not a

pedicle on which the animal is attached, as in some other forms, neither is it a tail: and yet this attenuation answers all the purposes of both, and many others; for by reason of it the creature can —like Milton's Imps—contract itself from its

FIG. 10.—*Stentores.*

otherwise giant extension to an infinitesimally small compass, and again expand at will to its normal length, 1-25 of an inch. Also, by this means it enters the condition of social life. A number will thus congregate together and form a social colony, each one secreting a viscid substance by means of which they attach themselves in groups to any object. Thus, if you collect a number and

place them in a glass jar or vase with a few sprigs of living plants, in a few hours they will be seen hanging in graceful clusters, head downwards, from the plants, the sides of the glass, or any other object near; and being thus grouped and extended to their full length, may be seen with the naked eye or with a hand-glass. In this way one may form an ornamental object for the table of great interest and beauty. Not all Stentors, however, are thus trumpet-shaped.

One fine spring morning I was walking with a friend through a part of Epping Forest, when we came upon a pond covered with what looked like the sooty deposits of smoke with which London householders are only too familiar; and the illusion was confirmed by these masses of "blacks" being drifted by the wind to the sides of the pond, and in ridges against any obstructing substance. Observing this, my friend remarked on the condition of the London atmosphere, and the distance these deposits must have been carried for the water so far out to be thus polluted. I had, however, seen a similar state of things before, produced by well-known animalcules; so dipping

my bottle in the water, I held up to view, with a pocket lens, thousands of active rolling dark bodies. These were the *Stentores nigri*, of various shades of colour, intermediate from black to blue. So numerous were they, too, that on dipping your hand in the water it would be withdrawn all covered with them; and on rubbing your fingers together they would be stained as if with black ink. Viewed under the microscope, these little Stentors are like so many "animated hats" (one familiar form of which they much resemble) tumbling and rolling about in wild delight. Both they and all the race of Stentors are covered all over with fine hair, or cilia, which, vibrating with life, enable them to perform such evolutions.

There are some Stentors which approach to a higher form of life, in that they surround the lower part of their tapering bodies with a gelatinous sheath or case, in which they take refuge on the slightest alarm, or when the surrounding fluid gets dry; they thus manage to retain vitality for some extra time. This power to secrete a mucous-gelatinous covering is of essential service at a certain period of their lives, when the important

operation of self-division has to be performed. This division is either oblique or longitudinal, and must embrace portions of the band-like nucleus with which they are endowed, and which, as in the Amœba, seems to embody the prime essentials of life. They have also a large contractile vesicle, which opens and shuts with regular pulsations. Around the crown, or expanded trumpet-formed head, the cilia appendages are longer than elsewhere, and are wreathed or coiled spirally around it, forming a very beautiful outline. A vascular canal traverses this coiled expansion, and with the long fringing cilia extends down one side the body in a gradually diminishing channel. Occasionally one gets a glimpse right down the widely expanded gullet, and observes the food passing into the several sacs or cavities which line the intestinal canal, and which were at one time considered to be so many stomachs; and accordingly the Stentors, along with many other similar organisms, were classed as *Polygastric*, or many-stomached animals. The lowest of mankind who live to eat are matched by the simplest forms of animal life; the difference being that whereas in the former a certain

degradation ensues, in the latter the result is an undoubted improvement, both in appearance and capacity. The Stentors feed incessantly; and if with bright green algæ, will so improve in beauty as to become objects of great attraction.

The *Stentor polymorphous* has, as its name implies, the power of changing its form; and, from being trumpet-shaped and attached in pendant clusters to some water-plant, it will detach itself and assume the form of a "thimble," open at one end and rounded and closed at the other, and in this form leads a free and active life, moving rapidly through the water. Their bodies are very plastic, and change rapidly—now gliding along in a shapeless lump at the bottom of the vessel, and anon, perched trumpet-formed on the head of another brother horn, appears as if blowing a blast or in stentorian voice delivering a message. Again a change, and they are all off, like so many animated tailors' thimbles: until, tired and weary, they resume their normal form, and are seen, grouped in clusters, hanging from a neighbouring bough.

Closely allied to the Stentors are the *Bursarinæ*. They are not, however, trumpet-shaped, but pouched

animalcules, or rather compound purses, for this purse-form is not confined to their exterior; the internal digestive cavities are little cells or pouches, attached by "short stalks" to the alimentary canal,

FIG. 11.—*Bursaria truncatella.*

and are capable of receiving and digesting large quantities of food, both animal and vegetable. The large aperture named a mouth in the *Bursaria truncatella* is lined with cilia, as is also its entire body, interior and exterior alike. Indeed the whole body is one delicate ciliated membrane or cell, in which are hung sundry digestive pouches; and the creature seems formed with a view to the

consumption of as much food as possible. The food in each pouch is seen to be surrounded by a clear liquid, which the celebrated German naturalist, Ehrenberg, considered to be bile. Such a creature may well be called *Polygastric.*

The quantity of decomposing matter consumed by these and all the Infusoria must be very great, and the purpose served by them in the general economy of nature very important; for, besides acting as scavengers and keeping the waters comparatively pure, they "arrest the fugitive atoms" of organic matter in their journey back to the mineral kingdom, and bring them again into the realm of food-forming material — *i.e.*, their own bodies, which, by their amazing power of increase, furnish the material of life-tissue to the higher and more complex animal world. Thus man himself becomes indebted to these humble beings for the abundance of his food-supplies.

The Bursars, like the Stentors, are endowed with a nucleus and contractile vesicle, and propagate by self-division, and also by means of internal germs or embryo. One very striking feature in the *Bursarinæ* is the extreme delicacy of their bodies,

Though comparatively large in their general outline, being about 1-15th to 1-25th of an inch in diameter and just discernible by the unaided eye, they are of such extreme tenuity as scarcely to bear the slightest touch, and, being extremely active, are thus very difficult beings to manage under the microscope. You want to stop its gyrations in order to examine its organisation, and having so large a creature to deal with, apply a gentle pressure to the covering glass with this object. Now, unless you are very gentle indeed, you find the Bursar has outwitted you, and disappeared in a thin cloudy mucous film. After many attempts you may succeed, and then are well repaid for your trouble, for these animals furnish the finest examples of ciliary action it is possible to imagine.

Like the individual, the whole lot in a locality will sometimes vanish suddenly and simultaneously (Bursars and Stentors alike); and, "like the baseless fabric of a vision faded, leave not a wrack behind."

IX.—HYDRA.

"Great Nature is more wise than I.
I will not tell you not to weep."—TENNYSON.

"Nature is always consistent, though she feigns to contravene her own laws. She keeps her laws, and seems to transcend them. She arms and equips an animal to find its place and living in the earth, and at the same time arms and equips another animal to destroy it."—EMERSON.

OF all the minute forms of animal life, perhaps none have excited more general interest and curiosity than the Hydra, or fresh-water polype, and this not so much from any special beauty in it, as from the truly wonderful properties belonging to its extremely plastic nature. To recite a few of these is enough at once to arrest the attention. What will be said to the following well-vouched-for facts? You may take a Hydra and cut off its head and engraft it on another; or you may exchange heads one Hydra with another. You may cut up one animal into forty or fifty pieces, and each piece will become a

perfect and completely formed Hydra; or, take a fine lancet and cut lengthwise from head to base, just leaving the latter united, and you have a double-headed Hydra with but one base; or reverse the process, cutting from the base upwards, just leaving the head untouched, and you have a single-headed animal with a double body. What will the anti-vivisectionists say to such operations as these? They may, however, take some comfort from the fact that even when the head is thus halved the arms belonging to each portion continue their operation in seizing their prey as if nothing whatever had happened; and the inference is therefore that not much, if indeed any, pain has been inflicted. So you may continue to play with this curious animal, and stuff one end of the body of one into that of another, and behold the two unite and form one hydra. It is even said—although some recent experiments throw doubt on the assertion—that, if with a fine bodkin the animal is turned inside out, it will perform its digestive function just as well as it did originally the other way.

When the Hydra is expanded, with its tentacles hanging gracefully down, as in the wood-cut before

us, it is rather a pretty object; but if one casts about for a similitude it is rather difficult to find one. The knotted cat-o'-nine-tails supplies a not inapt comparison, both as to form and function. A handle with knotted cord or thongs at one end,

FIG. 12.—*Hydra fusca* on *anacharis*.
A. Natural size expanded. B. Natural size contracted.

when wielded with a strong arm and falling on the back of a criminal, is said to sting; and here is an animal just of this form: a hollow or sub-cylindrical body, with from five to ten slender serrated or knotted-like arms springing from its head, each armed with poisonous stinging organs, which spring out with marvellous velocity at the moment of impact with its prey—killing some at once and

benumbing others, rendering them helpless victims, to be devoured at leisure. The Hydra is a voracious being, and attacks and devours creatures much larger and more highly organised than itself, such as small crustaceans, &c. The so-called water-flea is stunned by a gentle tap on its head with one of the Hydra's arms, and then drawn gently to the mouth and absorbed. After a while, however, the shell of the Entromostracan will be thrust out, sometimes in a perfect condition, the contents having been beautifully cleared out without any injury to the exterior. Small worms which live in water are a favourite dish, with which the Hydra will gorge itself when it gets the chance, so much so as to disfigure its entire body with them. One celebrated observer of the Hydra, M. Trembley, relates a contest which he saw between two Hydras for the possession of a worm, and how it ended by one Hydra swallowing the other and the worm together, and having absorbed the worm in its digestive cavity, quietly yielded up uninjured his troublesome but weaker brother Hydra. If, however, the Hydra is a good eater, it appears also to be a good faster, and seems capable of existing for days and weeks to-

gether without food. Stretching out its tentacles in search of prey, and, finding none, it will gradually accommodate itself to its abstemious condition by diminishing its capacity, and so live on till better times come round again. I have kept

FIG. 13.

A. *Hydra vulgaris.* B. Stinging organs magnified.

Hydras in this semi-starved state for a long time in perfectly clear water. They have nevertheless multiplied, though getting, as they say, "small by degrees and beautifully less" on water diet only.

There are two well-marked species of Hydra: the one green, *H. viridis*, and the other white or

brownish, according to the nature of its food or condition as to food-supply. This latter form is sometimes, or rather generally, divided into two species—*H. vulgaris* and *H. fusca:* the former a plump, well-fed, light brown fellow; and the latter white, thin, and attenuated. It is, however, highly probable that the difference is entirely owing to the question of food or no food; for I have seen the full and plump *H. vulgaris*, with its short stumpy arms, too lazy to extend them far beyond its own body, gradually change both in appearance and action as its supply of food became less and eventually was cut off altogether. It then lost flesh, and in the endeavour after food gradually threw out its arms further and further, until it would equal in extent any *H. fusca* in this its essential, or supposed essential, specific distinction.

The *Hydræ* are composed of a soft, jelly-like, cellular substance, capable of great extension and change of form and colour. It is a living tube of sarcode, having its principal concentration of power at one end, which is regarded as the head, and where is situated the only opening into and exit out of this wonderful tubular body, and whence

the arms or tentacles branch off, coiling about in all directions in search of prey. The other end is provided with a suctorial disc, by means of which the animal attaches itself at will to floating plants —thus obtaining the benefit of change of position without effort—or to any other fixed or movable object near. They are very sensitive to light; and if kept in confinement in a confectioner's glass jar, one may with a hand-glass watch their movements with great ease. They will collect on the side of greatest light; and if the jar is suddenly turned round, the long tendrils, though hanging down gracefully at the moment, will now stretch right across the body of water towards the bright side, as if anticipating the coming pleasure of moving in that direction, which they will do if undisturbed. The motion, however, is so slow, if unaided by any floating object, that a few inches distance takes as many hours to get over. This they accomplish in more ways than one. They will measure themselves by attaching the mouth or a tentacle in the direction required, and then bringing up the foot when the previous hold is dropped and expanded again for another step, and so on

until the goal is reached; or they will turn themselves over with a bound. Another method has been observed: by hanging head downwards on the surface, with the foot thrown out above, and thus floating with the stream.

There is very little of organisation in the Hydra; yet they are possessed of one extraordinary power in their stinging organs. If one takes a Hydra and places it under pressure, then with the microscope will be seen a number of small oval capsules (which the pressure has forced out on to the glass), with a long and fine point projecting out from each, as in the woodcut; and it is supposed that it is with these that the prey of the Hydra is secured and killed. It may be conjectured that these points are coiled up within the capsule, and are used only when wanted, when they spring out with force enough to penetrate their victims. The singular effects of this impact have led to the conclusion that these capsules contain poisonous matter, and this is apparently confirmed by some chemical tests. A worm, which is so tenacious of life that if cut in pieces each piece will live a considerable time afterwards, is yet instantly

killed by the touch of the Hydra. Yet the Hydra is not vicious, and kills only when it needs food, and then in the easiest possible way—killing the worm outright, and numbing other animals so that they suffer not. Although so destructive when in want, it is very tolerant of other creatures which it does not require for food—especially so to a small infusorian, great numbers of which are often seen swarming over it, and are apparently supported by what they get—as parasites—off its tentacles and body.

We have seen how the Hydra may be propagated by cuttings, and it may be here noted, that those thus produced are generally the finest, as is the case in so many other of the lower forms of life. The general method is by budding. A slight protuberance will appear anywhere indifferently on the side of its body, which gradually grows into a bud, and thence into a young Hydra exactly like its parent, to which it will remain attached for an indefinite time: indeed, if undisturbed, a second and even third generation will thus be formed, Hydra budding on Hydra, before a detachment is effected. The young thus produced eventually

sever themselves from the body of the parent, and begin life on their own account. Another mode of reproduction is by the formation of spermatozoa and ova. Both are formed on the same body, in small conical and sac-like projections. When maturity is reached, the sperm-sac bursts, and the contents, becoming liberated, fertilise the ovum, very much after the manner accomplished by the pollen of flowers. After being fertilised the ovum becomes invested with a thick and hard covering, drops off, and remains thus protected at the bottom of the water through the winter; and on the return of spring from these seeds or eggs new *Hydræ* are reproduced. Thus the Hydra, though differing materially from vegetable forms of life, yet shows some striking likenesses to them, especially in its reproductive processes—*i.e.*, buds, cuttings, and covered seed which germinates apart from its parent, &c.

Though not a displeasing object to the eye, but on the contrary very graceful in form and motion, the Hydra is yet one of those beings from which the gentler sentiments recoil. Their poisonous stings, their coiling arms—enveloping animals

much larger and higher in the scale of life than themselves—and the slow yet inevitable fate attending their movements, are all so many dread-inspiring elements. If to all this is added their extreme minuteness, combined with so much power, there arises almost a feeling of awe in contemplating the tiny creature, and we see that, if not the monster its fabled name implies, yet it is somewhat near akin to it and its larger marine relatives of which such tales of horror are sometimes related.

The *Hydræ* inhabit ponds, ditches, and slowly running streams, and *H. vulgaris* may be found in great abundance in the canals around London, attached to algæ and other fresh-water plants. The common weed *Anacharis*, which is so prolific as to have become a nuisance in our streams, is sometimes covered with them. At almost any time, if one picks up a little of this weed from the Regent's Canal in a bottle of water, one or more of these creatures will almost be sure to be seen depending from it; and if kept in a clear glass jar with clean water, the seven or eight arms will soon be seen stretching out in search of food. These arms will sometimes expand to a length of several inches.

X.—WATER-BEARS AND ROTIFERS.

"For nature also, cold and warm,
And moist and dry, devising long,
Through many agents making strong,
Matures the individual form."—TENNYSON.

"Loneliness takes life
As over its world
The invisible hovers."—UHLAND.

IT might be supposed that one of the most unlikely of places in which to hunt for animal life would be a gutter under the eaves of a house; yet this is one of the places where the "Water-bear" (figured on the opposite page) was first and is often now found. This can hardly be called its habitat or favourite haunt, or it would not have been named Water-bear; for although water is often found in roof-gutters, yet it is also as often absent. The fact is that these animals are here by accident, and not from choice. They are here against their will, so to speak; and this circumstance leads at once to the most extra-

ordinary fact about them. They, like some Rotifers, are so extremely tenacious of life that they will bear drying up into (to all appearance) fine dust, and in this condition are carried hither and thither by the wind; and so their being in the roof-gutter is accounted for. Here they lead a fitful and intermittent life of activity and repose, according to the

Fig. 14.—*Water Bear* (after Slack).

fluctuations of the weather—at one time dry as dust and scorched by the sun, and at another active in sentient life under the refreshing rain. It may be presumed that they would rather be always in the water; but ponds as well as gutters sometimes dry up. So they have in the course of ages accommodated themselves to these inevitable fluctuations, and are apparently well content with their present lot. Not much water, however, is necessary to their active existence; for they are often found

roaming in and about damp moss as well as in pools and ponds of water.

They have, however, acquired the very remarkable power of sustaining life under conditions which would be fatal to almost all other forms of organic life; for they will not only stand drying up, but will remain in that condition for an indefinite length of time; so that having once furnished yourself with some of this dry, dusty, and latent life, you may send them in a letter to your friend in Jerusalem, or anywhere else, or you may keep them in your cabinet for an occasional evening's entertainment. Thus taking this inanimate dust, and adding a few drops of water, you will have the extraordinary privilege of seeing—one might almost say—"these dry bones live." They soon show signs of animate life and eventually fully unfold and display all the activity of which they are capable, as if no interruption to their continuance had ever taken place. And in the case of the Rotifers these activities are so very pleasing that you will not very soon get tired of watching their movements. They gradually unfold and stretch themselves out, and after a few more move-

ments throw out the two little apparent wheels with which their heads are crowned. These appear to revolve on their own axes with great velocity, and present a beautiful and interesting pheno-

Fig. 15.—*Rotifer vulgaris* (after Ehrenberg).

menon; for, though the revolving process is only an optical illusion, it is so very like reality that no one unacquainted with the actual facts would for a moment suppose that it was otherwise than real; and, indeed, it was many years before this illusion was dispelled even in the scientific world, so that this apparent rotatory movement obtained for the

creatures the distinctive name they now bear—*i.e.*, Rotifers.

Having amused and instructed your friends with this wonderful sight, you allow the water once more to evaporate and place the dry dust away for further use. Or you may now proceed to yet severer tests; for both the little Water-bears and the Rotifers, after being dried up in the way here described, will bear intense heat before giving up the ghost. True they will not stand *boiling water*, yet they will stand *dry* heat up to 260° Fah., and hot water at 118° Fah. They have also been kept in a vacuum for thirty days, with sulphuric acid and chloride of calcium, without losing their capability of revivification.

Various theories have from time to time been propounded to account for these extraordinary phenomena, and much scientific and even theological wrangling has been brought to bear upon them. The Clericals on the Continent fancied that here, in actual organisms under our eyes, was found something like a demonstration of the doctrine of the "Resurrection from the Dead." This idea was strongly contested by their opponents; and

after a variety of experiments it was proved that the animals had not really been dead, and consequently that there was no resurrection. So the controversy passed into the realm of science, where facts alone have any weight and causes and effects are traced. As to desiccation and resuscitation, the facts are as above stated; and the cause or "reason why" is found in other facts which have been since discovered. These are, that the creatures are furnished with a very tough and elastic skin, and otherwise protected. In the case of the Water-bears two skins, one over the other, are found; and in the Rotifers there is also a slimy secretion, which hardens in drying, and forms an impervious coating; so when the drying commences they roll themselves up, with as much moisture as they can contain, into little round balls, cover themselves with this viscid secretion, and also generally get a little vegetable matter over themselves, and await their fate. There is also another important factor in the case, which explains why they will stand dry heat better and up to a higher point than wet. Their bodies are composed in great part of albuminate of soda or soluble albumen; and this substance when dried

will sustain a very high temperature without losing its soluble characteristic, and is thus admirably adapted as a vehicle for preserving the dormant life within its folds.

The Water-bears are hermaphrodite. They lay but few eggs, and these are hatched and the young nourished and protected after a very curious fashion. The eggs being deposited in the somewhat loose outer skin, and remaining there, the young, if brought into life in this position, would have no chance of escape but for the capacity which its parent possesses of throwing off this outer coil, which when the embryo is nearing maturity it does. The eggs are now thrown off with it; the young are herein hatched, and thus find a temporary refuge and sufficient nourishment until able to provide for themselves. These little Water-bears have obtained the scientific name of *Tardigrada* because of their slow movements. They are never in a hurry, and though subject to such terrible vicissitudes as we have here indicated, are always in good condition, fat and plump, and continually grubbing among whatever rubbish comes in their way. The mouth is a suctorial

organ, and passes on the food to a kind of gizzard, where it is rendered fit for the digestive process, and is then conveyed to the stomach, digested, and assimilated to the various tissues of the body. They are rather highly organised for such small creatures, having eyes, a brain, and nervous system, and may therefore be credited with some sort of conscious sensation. The sketch shows them to have four pairs of rudimentary legs armed with claws. These claws are not, however, weapons either of offence or defence, but simply the means of enabling their owners to climb about with great ease among the moss and plants in the water. Thus seen, fat and plump, making his way slowly and contentedly along, so small and yet so much resembling its formidable namesake, he irresistibly impresses one with a sense of drollery.

Nature presents many phases—or, in other words, life takes on many forms; but forms to touch one's risible faculties are not very common. There is something kind and tender in the droll little Water-bear, and we are glad to look at it. Indeed, one writer affectionately likens it "to a new-born puppy or unlicked bear-cub." Some

considerable difficulty has been experienced by the classifiers as to where they should place this queer little fellow in the animal kingdom. He has been bandied about very considerably, and for a time found a resting-place among the Rotifers. In some respects this was natural; for he is generally found living along with the common Rotifer (*R. vulgaris*), is about the same size (1-20th of an inch), has like it a shining transparent outer garment or skin, and like it is subject to and is capable of sustaining all the trials of drying, &c., to which we have adverted. But it is not a Rotifer after all; and having tried to fit him into some other places without success, the systematists have at length, as if in sheer despair, thrust him among the spiders. There is, however, no satisfaction in this arrangement; and while some think he should lie here and another there, others regard him as an anomaly, or a link between other and better-known and more definite organisms—say between the *Arachnoidæ* and the *Annelides*, or the *Rotatoria* and the *Helminthidæ*.

Taken all in all, the little Water-bear is about the most self-sustaining and independent animal in

this world. It will thrive upon food when it can get it, or do without it for an unlimited period. The kind of food is also a matter of supreme indifference to it, for it will either live on the juices of other creatures or among the *débris* of decaying animal and vegetable matter. Pure or dirty water comes alike to the Water-bear, or it will do without either, and grub among damp mosses for a livelihood, and, in the absence of even these, it quietly rolls itself up in its own skin and passes on the wings of the wind whithersoever it listeth. Though of relatively high organisation, it yet can do without a mate for the continuance of offspring; and these when they come give him neither care nor trouble, being, as we have seen, simply folded up in their parents' cast-off coats and left to shift for themselves. This is just such a creature as to stand the "wreck of matter and the crash of worlds," and almost answers the desideratum of some scientists for a creature that would bear the physical force of transference from one globe to another wrapped up in some form of mineral matter.

XI.—COMPOSITE ANIMALS.

"The man whose eye
Is ever on himself,
Doth look on one
The least of Nature's works."—WORDSWORTH.

"We penetrate bodily this incredible beauty;
Our eyes are bathed in these lights and forms."
EMERSON.

THE principal object in this sketch is a group of *Plumatella*, a form of fresh-water Polyzoa to which are attached stentors, rotifers, vorticellæ, and a beautiful tree form of epistylis. As they were all found together, so they are here drawn—not because there is any affinity between them, but merely that they formed thus, under the microscope, a picture of exquisite beauty and interest. Every one who is familiar with microscopic life has often found animals of various and diverse forms curiously combined: and, indeed, it is these wondrously beautiful pictures that constitute one of the chief

charms of microscopic work. The jaded clerk or anxious business man, half worn-out with the cares and routine of city life, is here transported to fairy-land, and finds his anxieties vanish in communion with the wonders of nature. Putting aside for the

FIG. 16.—*Plumatella repens*, with Rotifers, &c., attached.

time the rotifers, &c., you have a colony of this singularly beautiful fresh-water Polyzoon, with crescent plumes of delicate, tubular, ciliated tentacles, vibrating with life. Rapid currents are formed in the surrounding water, and the nutrient minute particles whirled within the plume and down the gullet to the alimentary canal, where you may observe the changes they undergo as they are rapidly digested and assimilated for the

creature's nourishment. These plumes are endowed with great sensibility and under perfect control; so that on the least alarm they are rapidly withdrawn, and with returning sense of security are again slowly protruded, folded as in a bundle, and presently expanding in all their glory, resume the normal activities of their being.

The general plan of organisation is much alike in all the Polyzoa. A tubular ciliated canal "bent back on itself" is suspended in a transparent membranous sac, to which it is connected. It is surmounted with the plume or crown of tentacles before named, forming the head and mouth and receiving the food, is endowed with all the functions of digestion and assimilation. The enveloping sac is filled with fluid matter, and furnished with nerves, muscles, and reproductive functions. It also secretes another membrane of greater strength on its exterior, forming a double protection to the delicate life within its folds.

It has several methods of reproduction, one of which is so intimately blended with its organisation that this seems the fitting place to mention it. This

is by gemmation, or budding. A small swelling or protuberance is observed within the interior membrane or sac near the apparent orifice whence the tentacles are protruded. This protuberance gradually increasing in size, at length assumes the exact form of the parent; and though still connected with it, yet commences life on its own individual account, and reproduces itself in like manner. A connected colony is thus formed, branching off in all directions, like the little twigs of a tree. At every joint there is a partial division; so that each little branchlet contains its own individual *polypide*, as in a cell or chamber, while still united to its nearest neighbour. In this way the colony is formed; and hence the name *Polyzoa—i.e.*, many-lives, or compound animal—is derived. In some genera this process is carried still further, and a second division is produced—as in *Cristatella* and *Lophopus*—where, when the colony becomes unwieldy, a separation, not of the individuals as such, but of the colonial structure, takes place: the reason of these exceptions being apparently because of the more delicate and softer nature of the investing membranes in these than in other forms.

Another form of reproduction is that in which small bodies are produced named *Statoblasts* (Fig. 17A). They are seen lying within the inner transparent membrane during the greater portion of the life of the Polyzoon, and have generally been spoken of

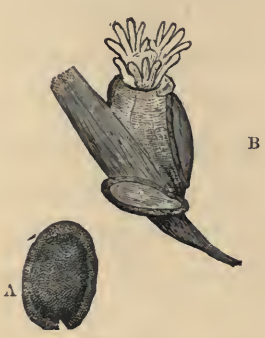


FIG. 17.

A. Statoblast. B. Young Polyzoon in process of development from a Statoblast.

as winter-eggs. They are of diversified form in the several genera and species—round, oval, or oblong lenticular bodies, which furnish by their shape, &c., a ready means of identification. In one instance they are furnished with hooked spines projecting from their margins. In all cases they are beautiful and interesting objects. Generally they are lying quietly and loosely within the sac investment; but occasionally one sees them being tossed up and down

like balls from the hands of a conjuror. There is no apparent way of their getting outside the sac; and, indeed, they never do until the parent dies or some accidental rupture is made. On the dissolution of the colony they escape, and may be collected in great numbers from the surface of the water. They are now very interesting objects of observation. One might be pardoned who was not familiar with them if he fancied he had a vegetable seed under the microscope somewhat resembling a small bean. On the approach of warm weather the statoblast begins to swell and the sides open, revealing not indeed the first tiny germ of a future plant, but a small and veritable animal, with expanded tentacles clothed in vibrating cilia (Fig. 17B). As it grows, the shell-like investment is dropped; and the creature floats away in the surrounding water, the destined founder of a future colony.

There is yet another method by which offspring are secured; and that is of a true sexual character, through the several means and stages of ova, spermatozoa, egg, and embryo in the same individual. In this instance, however, the young brood are not at all like their parents, but rather resemble ordinary

slipper-shaped ciliated infusorians. In this stage they are seen swimming freely about within the membranous sac of the parent; and here again, as with the statoblasts, one is at a loss to understand how they are to get out. The sac is closed organically round the two ends of the alimentary tube, and any rupture of it would, by letting out the internal fluid, be fatal to the creature's existence. At any rate, an important purpose is served by confining them for any length of time within it; for here their delicate structure is beautifully protected and nourished, and we see them grow and pass from stage to stage of development until the outline of the several adult organs are visible and all seems ready for their full expansion. Yet here they remain; and I cannot find that any one has ever seen them escape except by means of artificial rupture of the sac. I have found them free in open water, and, bottling some up once, thought I had found a new species of infusoria. The microscope, however, soon undeceived me, by revealing the immature and incipient structure of a Polyzoon. It is probable that they only escape or are born with the dissolution of the parent, as is the case with the

statoblasts. Being free, they now pass rapidly to the mature form, attach themselves to some aquatic plant, produce buds, statoblasts, and embryos in their turn, and so complete the circle of their individual and collective life.

Reverting to the compound or colonial character by which each member, though of distinct and vital individuality, is yet in some non-vital way organically connected with the whole, we observe that the several individuals form for themselves, or, more correctly, arrange themselves into, semi-detached apartments or cells. Generally these open one into the other, and some communication is kept up between each, which is presumably mutually beneficial; but in some instances these cells are partially, and in others completely, closed against their neighbours. So while living under the same roof—so to speak—social intercourse is suspended, except by contact from without, when the crowns of tentacles of the several individual polypides are protruded together. This is not always the case, for each one has the full power of acting for and by itself so far as its own individual interests are concerned, except that it cannot

altogether part company with the colonial structure. This compound structure is named the *Cœnœcium*, and is spoken of as "an assemblage of little cells" or chambers, in which the several members of the colony or polypides are lodged. It is, however, as we have described it, part and parcel of the polypides themselves, each little cell or chamber being an individual polypide, though united to a common whole by their investing membranes. These colonial structures of living animals are found generally attached by a viscid secretion to aquatic plants: some prefer the under-side of the broad leaves of the water-lily, where they spread themselves in an irregular kind of network against the leaf; others twine around the stem or on bits of stick or rotten wood, sometimes in large irregular masses or in spindle-shaped forms of considerable size; others are found twined in long branching colonies along with the coarse filamentous algæ at bottom of deep ponds or canals. I have found one of the most beautiful and largest forms—*i.e.*, *Lophopus crystallinus*—hanging like bright beautiful blossoms on the too common *Anacharis*, in the clear water of a shallow pond—a beautiful picture even to the naked

eye. There is one form—*i.e.*, *Cristatella mucedo*—which is exceptional. It loves the light, and floats about sometimes unattached on the surface of the water, and at others creeps about on the plants. Hence it is generally called the Travelling Polyzoon. It does not travel fast, however, and its method of locomotion is involved in some obscurity; but as the under-side consists of a contractile disc, it is probably by means of its contraction and expansion that it gets along.

The fresh-water forms comprise only a small portion of the great class of animals designated Polyzoa, which are mostly marine; but enough has been said to show that we have in our ponds and canals a beautiful and intensely interesting variety of this wonderful form of animal life; and moreover, they will bear domestication, so that one may keep up a stock of almost every variety in a few glass jars. Even thus seen with ordinary vision in clear water, with aquatic plants, they are very beautiful; and when required they will lend themselves without injury to gentle separation with a pair of fine scissors, for our more exquisite pleasure and instruction under the microscope.

XII.—THE SUN ANIMALCULE.

"He who feels contempt
For any living thing, hath faculties
Which he has never used."—TENNYSON.

"I am myself an irradiated manifestation of the Supreme."
RIG VEDA (Hindu).

THE *Sun Animalcule—i.e., Actinophrys sol*, belongs to a class of very remarkable animals. It consists of a small bit of globular protoplasm, with spines radiating in every direction from its surface; and, when seen in perfect condition for the first time under the microscope with proper illumination, it seems to shine "like the sun in its brightness." Hence the original observers gave it the name of *Sun Animalcule*. Indeed, any old ordinary picture of the sun would do very well for *Actinophrys*, as conveying a general idea of its form; though in another aspect the moon would be a more appropriate symbol of its character, for it shines with a

cold and silvery brightness rather than with the warm and golden rays of the sun. But of course these fanciful resemblances—for which we are

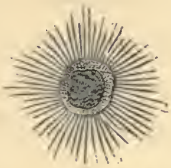


FIG. 18.—*Actinophrys sol.*

indebted to the quaint imaginations of the earlier observers—have no real meaning in the nature of things, although, as in this case, they give a

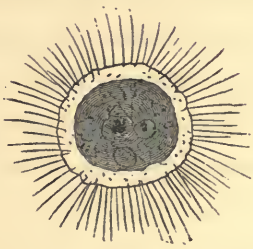


FIG. 19.—*Actinosphærium eichornii.*

popular idea of the object, and thus serve a useful purpose. And, viewed in this light, the *Sun Animalcule* has other resemblances than that of its globular form and shining rays to the sun; for, like

it, there are at least two zones or layers—namely, a bright and clear vacuolar ectosarc, covering a firmer clouded internal sphere, or (as it is named) endosarc. Dropping further resemblances to the sun and the moon, we see springing from this endosarc the pseudopodal rays, which are simply extensions of its own granular protoplasmic substance. These rayed extensions are very delicate and flexible tentacles, endowed with extraordinary power. There is a firm axis filament or thread starting from the body forming their base, by which the creature can stiffen or render them flexible, extend or withdraw them, at will. All these movements are, however, very slow, yet of a very pronounced and decided character. When the creature requires food these spinal rays are extended to their utmost length, far longer than the body, and, stretching out in all directions, are soon brought into contact with the more active inhabitants in their neighbourhood. A small rotifer or water-flea rushing past is sometimes apparently impaled on their fine points, which, in the not uncommon event of the struggle that now ensues, are assisted by other neighbouring spines being brought to bear on and around the captive,

which is thus secured and drawn towards the body of its captor. What now is to happen, for there is no mouth to receive it? We have seen that *Actinophrys* is a little rounded mass of life, with nothing of apparent organisation but those rayed spinal filaments, no mouth or other organs; and yet it has caught a highly organised animal, which it holds in its firm embrace, presumably for the purpose of using it as food. Presently a slight depression is observed in the soft protoplasmic body of the *Actinophrys*, which very gradually deepens and expands as its victim, the rotifer, slowly descends deeper and deeper to its doom in the interior. Here you may still watch it. It has ceased to struggle, and sometimes even seems to enjoy its novel position; for it is accommodating itself to its new environment, and sets its cilia in motion as if to obtain food. Not for long, however, is any motion visible. The soft parts of its body are gradually absorbed for the nourishment of *Actinophrys*, and the delicate shell or *lorica* gently expelled as gradually as it was drawn in, and without the slightest injury being done to it. How all this is done it is impossible to say, for

there are no apparent suctorial or other organs to do the work. Another and another rotifer is caught, and drawn as if by enchantment to the volcano-like craters opening to receive them. I have seen as many as five or six at once thus absorbed, causing utter disfigurement to the body of *Actinophrys*. There is not always a struggle, and as the finely drawn-out extremities of the tentacles are not visible, there is something terrible in this apparent fascination, as one after another of these beautiful creatures—the rotifers—slowly wend their way to inevitable destruction.

The *Actinophrys* extemporizes a mouth—just as the Amœba—wherever it needs one, at the surface of its body, and where the expanded rayed-out parts of its own substance happen to have come in contact with a possible victim. Its body is composed of granular protoplasm having cells or vacuoles, which act as so many stomachs in absorbing and digesting (each one on its own account) the food with which it is brought in contact, and reject waste products at any convenient point. Near the surface of the outer zone are seen generally two contractile vesicles—*i.e.*, sack-like projections of

greater transparency than the surrounding matter —which, after gradually swelling up to their utmost, give way so suddenly as apparently to shake the whole fabric, causing a visible vibration in the entire body of the animal. After a moment's rest they are seen to be again expanding and again col-

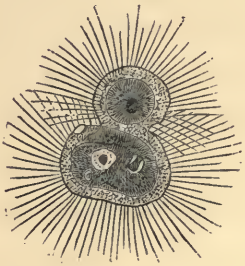


FIG. 20.—*Actinosphærium eichornii.*
In process of self-division or self-absorption.

lapsing. This process is ever going on at regular intervals, and these vesicles probably serve the purposes of respiration and circulation. In the inner zone are observed points or cells of greater density than the rest, which are termed nuclei, and are probably the prime seat of life and reproductive power. For it is observed that, when a certain process, now to be described, takes place, these bodies, of which there are several, but never fewer

than two, take sides, so to speak; one goes to one half and the other to the other. It is in the common process of self-division that this is observed. One sees a slight but gradually increasing constriction in the body of the creature, which on reaching its maximum of finely drawn-out matter separates, and the process is complete: the product being two beings where only one existed before; these two repeating the process, and thus they go on increasing in geometrical proportion to incredible numbers. Opposed to this is another process which I think may be called self-absorption, as this is its first apparent result. Two individuals will approach each other, and, coming in contact, will eventually become so fused the one with the other as to present the appearance of only one being; the only difference in the appearance of the new animal being that it is a little thicker or denser than either of the two of which it is composed. So they—or, rather, so this one remains; and no other result is seen for a long time. Patience and close observation are, however, eventually rewarded in this, as in all the ways of life. This apparent ending, though calculated to throw one off one's guard, is too suspicious

to be regarded as final. The first result of this process is the partial, and finally the entire, withdrawal of the rays and the darkening of the whole sphere, from which it changes to almost perfect transparency; and a very delicate membrane begins to surround the entire creature. Then a hitherto quite unobserved body, clear and transparent, appears, from which emanate numerous small bodies, presumably spermatoza, which, by impregnating the whole mass, finally results in the formation of eggs and the consequent reproduction of *Actinophrys* through the usual stages of embryonic life.

There is yet another method, which may be called binary segmentation: it is self-division in an unusual way. The spinal filaments are withdrawn, and a thin gelatinous exudation overspreads the entire mass. Then segmentation proceeds until the whole body is resolved into a mulberry-like sphere. Each component part of the berry is joined to its neighbour, yet having its own independent life and characteristic functions. On the conditions becoming favourable this covering is thrown off, and each little berry-like body develops into a full-grown *Actinosphærium*.

We conclude this description in the words of Joblot, one of the earliest observers of the seventeenth century, who, in describing this creature, says: "Surely, this is a fish the most extraordinary that one may see."

NOTE.—*Actinophrys sol* and *Actinophrys eichornii* (or, as it is now named, *Actinosphærium eichornii*), being so much alike in everything almost, except size, the one description applies to the two forms.

XIII.—STAR-LIKE ANIMALS.

"Between two worlds
Life hovers like a star."—BYRON.

"And living stars to view be brought,
In the boundless realms of thought."
W. H. FURNESS.

THE Acinetons are radiate and suctorial infusoria of peculiar interest, and on them a good deal of scientific discussion has been expended. In some respects they resemble *Actinophrys* just described; and it was customary at one time to associate them together. Subsequently they were regarded as temporary states only in the life-history of other organisms, and we were favoured with the acineton stages of *Vorticella*, *Epistylis*, &c. Finally, this theory was shown to be in error and abandoned; and the Acinetons were again regarded as *bonâ fide* separate existences, having a family

history all their own, which we shall now attempt briefly to describe.

After long and patient watchings one becomes impressed with a certain leading characteristic in respect of them, and that is their variability of ex-

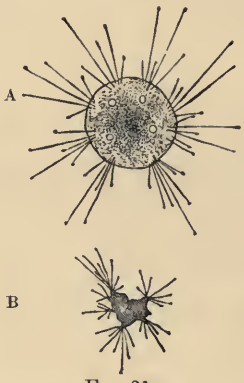


FIG. 21.

A. *Sphærophrya symmetrii.* B. *Podophrya quadripartita.* (Immature form.)

ternal form and appearance. Apparently rigid and definite, they yet turn up in every conceivable irregularity of outline, so that classification on this basis becomes a hopeless task. Nevertheless, it has been attempted, with the result of plunging the whole subject into obscurity and confusion; and while valuable observations are made, yet the charm is broken for the general reader. One result

of these minute divisions and subdivisions on this shifting basis is the production of a nomenclature which, being as useless as it is obscure, the first touch of subsequent investigators generally demolishes; but which the book-compiler continues to copy and to perpetuate for the mystification of those who may have courage enough to read his usually costly and uninviting productions.

In some cases the Acinetons are found as irregular lumps of jelly-like substance, clinging to the filaments of algæ, and covered with extraneous matter to such an extent that they would be unrecognisable were it not for the radiating tentacles which are observed here and there branching out in tufts indifferently from any part of the body—if we may call that body which is utterly without definite form. The only thing attractive about them in this state is their fine radiating tentacles, which, in some forms, streaming out in bright shining streaks of light, as it were, from a comparatively dark nucleus, form a crescent zone of radiating rays, and remind one of the *aurora borealis*. In this state they will continue for some time, reproducing themselves in small bright shin-

ing patches, and adhering to any object with which they happen to come in contact; and here the variability is so great that you cannot find any two alike — nor, except in one instance, have I ever seen any approach to definite form or symmetry. This one is here represented in the wood-cut, and besides being an exception to the general rule of irregularity, is an apparently new form. Yet it would probably be unsafe to give it a distinctive name, for one may never find another like it.* It has four contractile vesicles, placed equidistant from each other, and exactly double that number of bundles of tentacles placed at regular intervals around the circular transparent body—the whole forming a very beautiful object. Placing this one with the irregulars, as merely an exception on the one point of symmetry, and proceeding to note subsequent stages of development, it is seen that after a time the tentacles are withdrawn and all active signs of life are at an end. Nothing now remains but lumps and shining patches of apparently protoplasmic matter. Continuous observation becomes

* Nevertheless, as a name it must have, I have placed it with the *Sphœrophrya* as *S. symmetrii.*

irksome, is abandoned, and attention is given only now and then. Suddenly a total change in the aspect of affairs is observed. The dull and shiny patches have alike disappeared, and in their place are found the beautiful and more perfectly developed structure shown in Fig. 22A.

This creature (*Podophrya quadripartita*) consists of a bright, shining, four-cornered* star-like body with radiating tentacles, perched on a crystalline pedestal or footstalk, and attached to some other body, usually to that on which it was previously fixed; but occasionally they are found on the shells of small mollusca—*i.e.*, water-snails—where they are ever getting the advantages of locomotion and change without any effort of their own, or they are found on branches of the arborescent forms of other infusorial life. In this latter position they have played such pranks on the observers as to have deceived some of the most eminent naturalists, and were the primal cause of their own temporary expulsion from the systematic records. For they planted their own bodies in such an ingenious manner on similar

* They are not always quadrate or four-cornered, but vary in this as in all else.

structures, that mixing up their own acineton star-like forms among the ciliated cups of *Epistylis*, &c., and other known forms, the idea was suggested that the one comparatively well-known one was passing though an acineton stage of being, as indicated by the presence of these undoubted acinetons in their midst, which seemed to be part and parcel of their own organisation; and this idea was apparently confirmed by some similarity in subsequent development between the two. However, as we have already observed, all this was found to have been a mistake, and is now given up.

Returning to the perfect Acineton—*Podophrya quadripartita*—we now see certain small circular bodies being pushed up, as it were, gradually towards the margin of the upper surface of the body. (It should here be observed that in these creatures there is no mouth, or orifice answering to it—that the body is of a granular texture and fed by suction from tubular tentacles, and that out of this semi-fluid mass the small bodies now observed are produced, and eventually discharged.) These are free embryonic forms, totally unlike their parents. Making up for the

immobile parental form the young are, on the contrary, very active; they jump and dart about with great rapidity, are fringed with cilia, and may easily be mistaken for other minute ciliated infusorians. There is reason to think that such has been the case. However this may be, let us now try and watch the active ciliated body before us. This is no easy task; at last, however, one stops its gyrations and rests on a bit of algæ. It is undergoing a change; the cilia disappear, and a slight projection is observed at the point of greatest density, where a pedicle is gradually developed. This gets fixed to the weed. Now the body begins to enlarge, and gradually little by little the well-known corners appear, and the shining tufts of tentacles are produced; and, finally, you have a mature Acineton under your gaze. All this transformation is sometimes effected in about an hour or so. It is not always, however, that the process is of this rapid and continuous order. Sometimes the little ciliated embryo takes a turn at multiplication on its own account, and, instead of at once developing into a full-blown Acineton, chooses to perform the common process of fission, or self-division, before pass-

ing on to the mature stage. Then two or more go forward to this condition where only one would otherwise have done so.

Another form of the *Acinetina* (*Dendrosoma radians*) resembles a gnarled and irregular tree, with stumpy branches, from which the characteristic radiating tentacles emanate. It is rather rare; and until lately its history was involved in obscurity. It has now been shown that, in addition to the methods already described, this class is propagated by means of spermatozoa, very much like that already described in *Actinophrys*.

It is important to notice the character of the tentacles in *Acinetina* as contrasted with those in *Actinophryina*. In the latter they are finely pointed spines, which pierce and draw the prey to the body, where a mouth is extemporised to receive it. In the former they are tubular and tipped with suctorial discs, which spread a little around the captured victim. Small infusorians coming in contact with them are instantly arrested in their course, and compelled helplessly to adhere, while the Acineton draws out their soft interiors. In clear speci-

mens you may see the fine limpid life-fluid passing through the transparent tubular tentacle from one body to the other. The captive is not drawn towards its captor beyond the point of the tentacle,

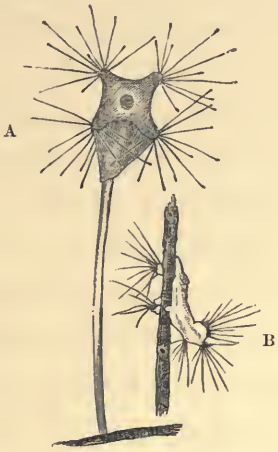


FIG. 22.
A. *Podophrya quadripartita.* B. Immature form of ditto.

where it is held until all its internal juices are sucked out, and what remains is simply dropped from the suctorial organ and allowed to float away in the surrounding water. The tentacles of the Acineton are withdrawn very slowly, and apparently with some difficulty. The habit of holding off their prey necessitates or induces a certain rigidity;

so, when the drawing-in process is commenced, the tubular tentacle assumes a spiral form, which allows of its being coiled up to a certain extent and reversed on its again expanding. Thus they are emptied of their contents into the body, and kept always free for the suctorial process whenever opportunity occurs.

In reverting to the very variable character of the *Acinetina*, one is somewhat helped to a comprehension by contrasting it with the same character in the Amœba. In this latter we have a small bit of jelly-like matter, which, Proteus-like, changes its form continually while under your observation; but in the *Acineta*, though the several changes are probably quite as great, yet each individual, however much it may be unlike its fellow, rigidly preserves the one form it has originally acquired. Thus the changes of form which in the one case takes place in the individual, in the other is spread over many. The form the individual Acineton gets is fixed until some important function of its little destiny has to be accomplished.

XIV.—SOCIAL "CROWNED HEADS."

"Only so far as the masters of the world have called in *nature* to their aid, can they reach the height of their magnificence."—EMERSON.

MEGALOTROCHA and *Lacinularia* are in some respects very much like *Conochilus*, described in No. II. There are, however, differences enough to give them a distinctive character both as between themselves and the latter form; for, although they all belong to the *Rotatoria*, and are all social in their habits, living in closely-packed colonies, yet, while the *Conochili* are free and revolving, the others are attached to the stems and leaves of plants or other objects. "In *Conochilus* the aggregation is round a central globule of gelatine, from which they project like so many rays."

This is also the case with *Lacinularia* in their free colonial condition; and even when attached

there is this rather profuse gelatinous investment. But in *Meglatrocha* the aggregation is centred to a fine point on a leaf or stem of a plant, from which they radiate in all directions. They will attach themselves thus to the glass sides of

FIG. 23.—*Megalotrocha* (*albo-flavicans*).

a zoophyte trough, and in this condition form a circular colony.

The *Conochilus* is found only in ponds and still water, while *Lacinularia* and *Megalotrocha* live in gently-running streams. Yet, although there may not be much danger of confounding the two latter with the former, there is so great a likeness between themselves, that, unless one gets acquainted with their specific minute differences, they may easily be

mistaken the one for the other. Further, in all three there is so great a likeness in general as to suggest the idea of a common origin, and to make the inquiry into their affinities and into the cause or causes of their divergence a subject of special interest. This is one of the chief charms in the study of Nature since Darwin furnished the key to the inquiry; and when we find those similarities accompanied with yet specific differences enough to have led former naturalists to set them (as in this case) in different families, one naturally looks around for some explanation sufficiently feasible to account for those differences.

What special circumstances, for example, could have led to the formation of the free and revolving spherical condition which we find in *Conochilus?* Presuming it to have descended from the same ancestor as *Lacinularia* and *Megalotrocha* how has it acquired a habit and motion so different from theirs? Or the question may be reversed, and by assuming the latter to have descended from *Conochilus,* or even both from another form not present to our inquiry, still the question as to the origin of the differences, and the in-

teresting inquiry "how acquired," remains for investigation.

Presuming a common origin, why is one free and revolving, and the other non-revolving and fixed to a local abode?

The answer is suggested by the terms of the inquiry, especially so if the difference of *habitat* be included in it, for it is easy to conceive how a comparatively slight difference in their surroundings, caused by some accidental circumstance in the first instance, may have separated the original family, and given each a new environment, to which it would endeavour to accommodate itself, and in so doing a modification of structure or motion or both (the one acting on and influencing the other), would result. So an upheaval or depression of the surface of the earth may have separated or cut off *Conochilus* from its fellows, leaving it for ages in comparatively still water. Under these circumstances a great advantage, or perhaps rather some compensation, would be gained if a free and revolving motion—such as we find it to have—could be obtained. It is remarkable that this revolving tendency exists in both *Lacinularia* and

Megalotrocha. In both the young brood is often separated from the parental surroundings, and for a time lives a free rolling life, and may in this condition be easily mistaken for *Conochilus;* also with the *Megalotrocha*, if a portion of even a mature colony be separated and detached, it at once commences, though rather awkwardly, a slow and revolving motion. Indeed, a social colony, whether of Rotifers or any other form of life having a ciliated surface or disc, must by the action of this cilia, which creates vortices and whirlpools in the water, tend to produce a revolving motion of the whole colony.

Nothing can be gained by this motion with either *Megalotrocha* or *Lacinularia*, whose *habitat* is moving water, and consequently we find that they soon settle down to a fixed and permanent attachment; but in the case of *Conochilus*, cast off from the running stream and confined in still water, this motion, by aerating the water, would be the natural compensation for the loss sustained, and if, as may be presumed, some sensations of a pleasurable nature were added to the undoubted physical advantage; this motion would be perfected by in-

cessant application; and would probably result in other beneficial modifications of structure to harmonise with it.

It should be further observed, that in the still water habited by the *Conochilus*, there is no danger attending this motion corresponding to that which would be the case in open running streams, where such delicate bodies would every now and then be in danger of transportation by floods beyond the sources of their regular food supply. Hence the attachment to water-plants, in the case of *Megalotrocha*, *Lacinularia*, and other allied organisms, and the power temporarily to do so by other more active and powerful creatures. The banks of the ponds (under the water-worn and projecting edges of which *Conochilus* is generally found) afford sufficient refuge, when the rising waters threaten them with danger in this direction.

It is thus that Nature ever works; adapting herself to ever-changing conditions, and evolving new forms and varieties of life and motion.

In the almost infinite variety of forms which life assumes on this earth there are but two great

channels in which it runs. One is in an ever-improving and progressing form. The other, retrogressive, sinking lower and lower to the dull lethargic parasitic condition. Between these two currents or tendencies there is, and must ever be, the greatest antagonism. For the very effort to improve the individual involves the improvement of its environment, and thus necessitates the removal or extinction of the parasitic class, which not only *obstruct*, but, as they sink lower and lower in the scale of degradation, eventually become absolutely loathsome, ugly, and repulsive, and require the most energetic and strenuous action for their destruction.

This is a law of life of universal application, although a merciful toleration is voluntarily extended where the position of the better sort may enable it to be done without danger; but otherwise it is ruthless in its application, being animated not only by the instinct of self-preservation, but by the nobler aim of arriving at the highest possible physical and mental state.

We do not credit our tiny friends here under description with any conscious intelligence in this

matter, or yet with any great power over their environment; yet the law here indicated is very strikingly illustrated in their history; and having praised the Rotifers so much, one is glad to notice that they belong, as a rule, to the improving class of animal life; so we trace a gradual and progressive advance from form to form, until we arrive at apparently the highest limit of perfectibility of which they are capable :—

Complex structure, having circulatory, muscular, digestive, reproductive, and nervous systems.

Active in their habits, life with them seems one of never-ceasing energetic motion—the wonder of all observers.

Beautiful in form, as with their flexuous, shining, crystalline, and transparent bodies, surmounted with rotary crowned heads, in which are set the finest of ruby-like eyes, they expand and contract, and disport themselves in every conceivable attitude, with perfect individual independence, yet in mutual harmony—no jostling or confusion, though so closely attached; now opening their flower-like crowns in rotating or wavy motion, then withdrawing and everting them within themselves, and again

opening and expanding; then on the approach, or in apparently nervous apprehension of danger, the whole colony suddenly shrinking or collapsing, and being enfolded within an hitherto unperceived refuge (a gelatinous envelope, the combined product, as it is now the common refuge, of each individual member, always in order, and ready for every emergency), and now again slowly coming forth, as the sense of security returns, in all their flowing, flossy, shimmering loveliness. No one can contemplate them without feeling the blessedness inherent in the innermost circle of Nature's operations, and rejoicing in perception of the meaning of such beneficent tendencies.

The gelatinous or jelly-like refuge above referred to is a beneficent arrangement as a protection and defence, and also as a bond of physical union. Lift from the water a sprig of the *Anacharis* to which these creatures are attached, and you see them as minute patches or droplets of jelly, which, holding sufficient moisture to sustain life for a considerable period, also serves as the best protection against rough usage or accidental impact with hard bodies. Replace the plant in the

water, and this jelly-like substance is soon seen to yield, and its contained occupants to be spreading out their flexible bodies in radiating clusters, none the worse for their temporary sojourn on dry land.

For more minute examination we again lift them from the water, and with a pair of small scissors detach one or more of these colonies from the plant to which they have attached themselves, place it in a glass trough, and so on to the stage of the microscope. Here, with a low power—say 1 or 1½ in. objective, and with a dark-ground illumination—the whole colony may be seen at once, and their form and motions observed with pleasure and delight. They are seen to be of a yellowish white colour, with soft flexible bodies — not divided into segments like insects, but constructed in yielding, graceful folds, one part overlapping the next, and easily slipping into each other in telescopic fashion. The head is heart- or horseshoe-shaped—a crown of beauty, fringed with a double row or wreath of vibrating cilia, which, when in motion, gives it the rotating character so much admired and so conspicuous.

This vibratile motion brings the fine particles of decomposing animal and vegetable matter in the water to the mouth, which is situated just in the bend of the heart-shaped crown, whence, by the same action, it is carried down the gullet to the complex gizzard or masticatory apparatus, and triturated or ground down to the finest imaginable pulpy material for digestion and assimilation in the tissues of the body.

The trochal crown or head is not an open orifice, as, from the lappet-like expansion of the ciliated disc which runs round, one would at first sight be inclined to suppose, but is covered with a fine, gauzy, delicately-marked, and figured membrane, which, at times, is gently raised above the surrounding ciliated disc, as if from an upward pressure from beneath, where are situated the eyes and nerve ganglia, or brain. The most prominent distinguishing characteristics in *Megalotrocha* as compared with *Lacinularia*, are four white opaque dots, placed like a row of pearls around its neck. These are equi-distant from each other, except at the bend in the crown, just below the mouth, where the distance

between them is greater. Their function is a puzzle as yet to the naturalist, though, doubtless, such prominent objects serve an important purpose in the economy of their possessors. The upper membrane over the head is also dotted over with similar, but much smaller, bodies, shining out with opaline tints.

The ordinary method of viewing those creatures is by means of light reflected by a mirror from below the stage of the microscope through a paraboloid, or spot lens, thus showing the object in a soft, delicate light on a dark ground, very charming and agreeable. There is, however, another plan, concerning which a celebrated authority on this subject recently wrote to me thus (speaking of the *Megalotrocha*, some specimens of which I had sent him) :—"Have you treated it at night as an opaque object, condensing a very bright light from above on the group? It is such a charming object seen thus. The brilliant white spots, delicate blue stomach, brilliant ruby spots on the sides and elsewhere, and yellowish head, mastax, &c., make an assemblage of colours rarely seen in a Rotifer."

In this group—*Megalotrocha albo-flavicans*—we seem to have reached the crown of social rotatorial organisms. Individually, the size of a Megalotrocha is about 1-36th of an inch in length, a slender body, tapering off into a foot-like tail, from which a sticky, gummy substance unites it to its nearest neighbour and to the plant or other object on which the whole colony rests. It has eleven pairs of muscles, two jaws (with teeth), water vascular canals, two eyes, cerebral ganglia, stomach appurtenances, and reproductive organs, all perfect, and in so small a compass! Yet are they the largest of all the associated *Rotifera;* and, as a full-grown group expands itself, one looks across their long and finely-transparent bodies as through a forest of animated trees, the upper parts of which are dense with the foliage of complex organs, while the trunks are bare and transparent, standing out in radiating, yet closely-compact, lines, through which objects beyond are clearly visible. Of a sudden, the whole forest-like colony contracts with a rush, to which in imagination one may listen for the sound. It is only for a moment, and again they

are extended and expanded in all their glory—the *sovereign*, yet *social*, crowned heads of the Rotifers.

In reference to the position which the *Rotifera* occupy in the scale of animal life, it should be noted as a fact of great significance that in their history there is no intermediate or larval condition after birth. All changes or metamorphoses take place in the egg, whence the embryo emerges as near the exact counterpart of its parents as generally obtains in the larger animals with which we are familiar. There is an apparent exception to this rule in the *Floscularia*, but it is of a very slight and transient nature, and it stands out as a remarkable fact, indicating or calling attention to the general rule, and pointing its importance and meaning, which may thus be stated:—Presuming, or taking for granted, that the progress observed in organic forms of life, from very simple to very complex conditions, is not achieved or produced by leaps and bounds, but is rather slowly—and, it may be, even painfully—reached in a severe struggle for existence, it follows that when a creature, however small, is found having a very

complex organisation (although we may not be able to trace the intermediate stages or forms), either in its individual development or in its tribal history, yet we are warranted, in view of the general law here indicated, in inferring that a series of gradations in organic structure have really been passed through before the complex organism under notice could have arisen. This argument applies with great force to the *Rotifera*. Being so small, they were originally classed with the *Infusoria;* but on closer examination of late years they were seen to be very far removed from the *Infusoria* in complexity of organisation, and were accordingly re-classed. The gap between them, however, is not filled up by known-existing forms showing the several upward stages, although, when the *Rotifera* form is observed, this gradation from one to another is easily seen and traced. Yet, because we cannot find the missing links between the *Infusoria* and the Rotifers, we are not justified in ignoring their existence in the ages that have passed away. And we thus come to contemplate the Rotifers in a new light, having a remote ancestry, and passing through severe strug-

gles, ever upwards, and through all difficulties, arriving at length, considering their minuteness, at perhaps, the most wonderful perfection of any known creatures on this earth.

XV.—A SUBAQUEOUS CITY.

NATURA NATURANS.

"Itself surest and indescribable variety; it publishes itself in creatures, reaching from particles and spicula, through transformation on transformation, to the highest symmetries arriving at consummate results without a shock or a leap."—EMERSON.

ON the same plant with *Megalotrocha* or *Lacinularia*, one often finds small patches of whitish-gray matter, looking to the unassisted eye so very much like the associated groups of these creatures as easily to be mistaken for them, yet no two forms of life, when closely examined, are more dissimilar than are the social Rotifers to this, the fresh-water Sponge, *i.e.*, *Spongilla fluviatillis*, of which we now write.

Placing them together in the same zoophyte trough under the microscope, the contrast is seen to be very striking. Instead of a group of active radiating beings in ceaseless motion, we have, to all appearance, a dull cobweb-like mass of opaque

matter, from which bright and glistening thorn-like bodies are projected in irregular diffusion. The entire body is thus seen bristling all over like the skin of a hedge-hog.

FIG. 24.—*Spongilla fluviatillis.*

These thorn-like bodies—or spicules, as they are termed—appear so embedded in the tissue of the Sponge as if intended to sustain, distend, and expand it for a specific purpose; and now, as we look more intently, a number of small irregular openings or pores, are visible, into which currents of water, carrying with them fine particles of dust-like material, are gently flowing.

Presently an elevation of a finely transparent membraneous nature slowly appears; wide at the base, and graduating upwards, it finally tapers off into a tubular or truncated cone, from which a stream of water, with contained particles of other matter, is shot forth with great velocity, as if from

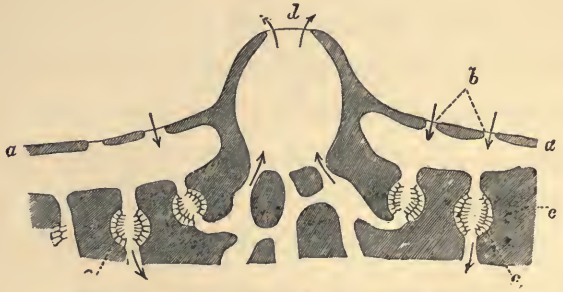


FIG. 25.—Hypothetical Section of *Spongilla*.
(After Huxley.)

(*a*) Superficial Layer; (*b*) Inhalent Apertures; (*c*) Ciliated Chambers; (*d*) An Exhalent Aperture; (*e*) Deeper Substance of the Sponge.

The Arrows indicate the direction of the Currents.

the mouth of a miniature volcano, so that small infusoria or other minute material coming near the orifice and in the wind of the current, are caught up and whirled rapidly away with it.

So far, even with the microscope, one could hardly imagine this to be a living organised being, or combination of animal life; for, excepting this

transparent cone-like elevation, there is no more the appearance of life than even in Vesuvius itself, with its rugged sides and vomiting crater.

On the principle that "where there is smoke there must be fire," we now seek for the hidden cause of this singular phenomenon, this inrush of water and its rapid propulsion from an apparently inert mass of matter. As we cannot see through or beneath this thorny filmy covering, recourse is had to the knife, and by cutting it open or taking thin slices for minute examination with high powers, the mystery is unravelled. Here in the interior are seen small circular chambers and channels, opening outwards and leading inwards, in every direction through the entire Sponge body, all converging in a central large cavity or chamber, and thence up and through the membranous tubular elevated vent. Through all these mazy labyrinths the current is flowing with ever-increasing force to its final outflow.

Increasing the magnifying power, and retracing our steps, so to speak, along the passages and chambers of this singular structure with our now more powerful vision, the hitherto invisible agency

is revealed by which this motion is produced, in a multitude of infinitely small semi-independent organisms or ciliated cup-like cells, from the centre of each of which is projected a comparatively long whip-like cilium, which, by lashing the water into ever-increasing velocity, eventually propels it through all the chambers and passages and out into the terminal mouth or oscule. These active agents which line the walls of the passages and chambers bear a striking resemblance to, if indeed they are not exactly alike, certain classes of flagellate monads which are found in associated groups as distinct forms of infusorial life in great variety; the only apparent difference being that here they are found with their cup-like bodies turned inwards, and attached to a soft yielding protoplasmic substance, instead of to a plant, in the open water. Whipping the water, however, is not the only object accomplished by these ciliated zooids. As the current is passed on from one to another, the nutrient matter held by it in solution is absorbed by these active workers, and feeds them, while the surplus passes on to their nearest neighbours, to whom they are attached by a physical bond. Strangely enough,

these, too, are, in other conditions, known as a distinct class of independent bodies, which, free in their ordinary localities, are here attached to each other and to the flagellate cups. These neighbours are the *Amœbæ* described in No. VII. Here in the Sponge they are found in "various stages of development, constantly undergoing changes of form and position. Uniting together their long slender *pseudopodia*, they form a complete net-work" of living flexible contractile material, combining all the functions of nerve and muscle. Not only are they thus diffused in lateral spreading combined masses, the living basis of Sponge structure, but they also multiply, and produce new colonies of Sponge life, by occasional detachments of their own substance from the general mass.

The Sponge may therefore be regarded as a metamorphosed Amœba, combining in one body the characteristics of the otherwise two distinct forms of Flagellate infusoria and Amœba, thus forming a compound and somewhat complicated organism, yet having a distinct and easily-recognised individuality, ultimately resulting in a pro-

duct of great commercial importance. Perhaps no more striking illustration could be found of the truth of the adage that "union is strength" than here in these two lowly, and, in their isolated individuality, helpless beings, yet who, in their combination, raise themselves in the scale of life, and produce a structure combining all the functions of higher and more complex organisms; having no stomach, yet perfect digestion and assimilation; no heart, yet free and full circulation; no lungs or gills, yet complete aëration and respiration; no manipulatory organs, yet building up a structure combining all the requisites of strength and endurance, with the most wonderful lightness and flexibility.

The Flagellate cells are apparently the most active workers, while the Amœboids form the ground-work of the colony, yet also aiding by their expansions and contractions in the general movement of the currents through the several passages and the elevation or depression of the crater-like vent. Nerve, muscle, and reproductive work belong principally to the Amœba, as also the secretion and development of the structureless external

investment and skeletal spicula, while the more active food-collecting, circulatory, and respiratory functions devolve on the ciliated or flagellate monads. This combination of material and forces, resulting in what we denominate a Sponge, though apparently so simple, is not at all easy to understand or to explain. Let us, then, bear in mind that in this combination the two forms—*i.e.*, Flagellate infusoria and Amœba—are fused or amalgamated in one essential histological element or life-tissue, which must now and hereafter be regarded as one combined structure or individual animal body, while at the same time each form preserves its own essential function and work. This combined oneness with semi-independence is characteristic of all complex organisms, giving rise to that general law of division of labour with unity of purpose so essential to the welfare of the whole body. The complexity of Sponge structure and function is, however, of the simplest order—paradoxically though it sounds—consisting mainly, as we have indicated, of only two primary agents, which, by their united and combined operations, have succeeded in producing a very interesting form

of life—a kind of "subaqueous city" (as Professor Huxley terms it), yet differing from all other cities in this, that they themselves are at once the inhabitants and the city-like structure.

This Sponge city, like most other cities of commercial importance, is built on the banks of a river, which intersects and permeates its every part, bringing food, and all the requisites of health and prosperity to the inhabitants. These latter build themselves into over-arching passages and grottoes throughout its entire length and breadth, living on and over the river, drinking in its life-giving element, and so completely identifying themselves with it as to make its currents perform the life functions of circulation and respiration analogous to that obtainable by a more complex method in the higher animals. So the river and the Sponge go together in Sponge life; for, while the water external to the Sponge is not dependent on the Sponge, its form and motion as a river or running stream through the Sponge city is produced by the latter, and may, in this sense, be said to be so. Yet the Sponge itself is absolutely and entirely helpless without the former

—the river or life-current of its continuous circulatory and respiratory functions, on which its very life depends from moment to moment.

Contemplating this miniature Venice-like city, one feels that something more is requisite to render it complete; for, although unlike the City of Waters to which we have compared it, in this, that its living activities are all inclosed, opening in upon themselves, and exposing only their basal structure to the external world, yet, even so, a defence and protection are essential to its well-being and preservation. And this the Sponge has not neglected; indeed, it has made defence its especial care, so that a stranger—say a Stickleback—on approaching it from a distance, sees only these defences, and, if not previously acquainted with its structure, would hardly imagine it to be other than a mass of prickly non-living matter. Its spicular investment is composed of one of the hardest and most enduring substances known, spreading over and imbedded in a soft, structureless, membranous tissue, which it at once upholds and protects. Thus, while tenderly surrounding the living city, and offering the most formidable defence to vio-

lent enemies, it at the same time allows full ingress and egress to the life-giving river which runs through its midst. What more could it do? What more could we do in like circumstances?

We do not credit the Sponge with conscious intelligence; nevertheless intelligence there is somewhere, and united with, or manifested in and through, such a humble form of life, appeals with irresistible force to something akin to it in our own breast—a responsive divine echo, saying, "I am here also."

A very striking feature in our Sponge city is the osculum, which, rising to a great height, like a vast chimney built by man to carry off smoke and poisonous vapours from burning furnaces beneath, seems designed for a similar purpose, for all the effete and waste matter of the Sponge community is carried off by this exhalent funnel, and to such a distance from the pores as to prevent its return.

The structure of this funnel is remarkable, being composed of an extension of the membrane, drawn out to the finest gossamer-like tissue, so that its weight does not prevent its being carried out and extended far beyond the boundary of the colony or

city. It is so fine and transparent that under the microscope the river, bearing on its bosom the refuse of the city, and also minute objects on the other side of the tubular structure, are readily seen through it. The power which raises and sustains this funnel is astonishing, when the invisible agencies are considered. This filmy structure, distended to its utmost length and kept in position, with its tubular sides almost rigid, so as to allow a free and unimpeded passage to the rushing current of water and refuse from the internal cavities, requires such an amount of muscular force as to excite our utmost wonder. It is also under perfect control, and is contracted and expanded at will; and in the presence of danger both it and the pores are temporarily closed by the inhabitants beneath. Draw off the water suddenly, and this distended osculum falls over, and is raised again after considerable time and labour with apparent difficulty.

Like most of the lower forms of life the Sponge has several methods of reproducing and propagating its kind. One of these is by a process somewhat analogous to that which is adopted in the vegetable

kingdom by means of seed and bulbs. Certain cells of the Amœboid character are specialised for the purpose, and amalgamating or coalescing, develop a horny coat of great strength and endurance, and also at the same time an internal spicular frame or skeleton of very singular structure—a "two-toothed disc, like a cogged wheel united by an axis." As this disc-like spiculum enlarges, the corpuscular germs, or Amœboid cells, disappear, and to all appearance nothing is left but the horny coat and its contained silicious skeleton. The living germs are hidden somewhere, and protected during the season of winter. One may here remark on the nature of the seed covering—horny and flinty—and wonder how the hidden life is ever again to make its way out through such material. Certainly, some vegetable seeds have very hard and woody shells; yet, even so, the germinal life would remain dormant, unless planted in the earth and softened by rain and dew; but the *Spongilla* seed has been formed in the water and made to resist its action, and unless some special provision is made it must remain dormant for an indefinite period. On closely examining these little circular seed-like bodies, a

small pore-like opening is observed at one point, and on penetrating this another is found in the spicular skeleton beneath, on the axle uniting them. Here the latent germinal life is interned, as in a cyst, and hence it issues, when the warmth of spring wakes it up. Then slowly emerging thence may be seen a number of minute corpuscular Amœboids making their way into the surrounding water, and eventually attaching themselves to any object near, when they proceed to develop the latent peculiar Sponge life with which they are charged. The flagellate cells are produced, perforations are made to the external water, chambers and canals are tunnelled, the ventriculus, or large central cavity, is excavated, the osculum is raised, the external defences completed, with a bustling net-work of silicious spicules; and the new Sponge city is built up and in full activity on the rushing river of its own creation, the exact counterpart of its long-ago autumnal ancestor.

Another method is observed in the summer, when a transformation of some of the flagellate cells is effected, by which they become specialised into sperm and germ, or male and female units.

The former undergo a process of granulation, and become filled with small flagellate rod-like spermatozoa, which eventually escape, and coming into contact with, are absorbed by, the now mature nucleated germ cells. These are thus impregnated, and in this condition of a fecundated egg, pass through the usual process of segmentation, the contents assuming the morula or mulberry-like state, followed by the external development of cilia, when the egg-form embryo by its means is enabled to swim about as an independent organism in the surrounding water. There is no hatching process of this egg. It is itself the young Sponge in embryo, working out its destiny to the mature Sponge city before described.

This sexual development does not seem to be necessary except as a sort of more vigorous renewal or reproduction, and is in consequence only occasionally resorted to. The more common method being the production of non-sexual egg-like formations of the Sponge tissue, which are at once set free in great numbers as ciliated embryos, through the osculum, and then go through the usual subsequent stages to perfect Sponges.

The Sponge is wonderfully tenacious of life, and will undergo propagation by cuttings; or it will multiply itself voluntarily by the analogous process of self-division, or, reversing this process, it multiplies the Spongy bulk by diminishing the number of individuals, by a process of fusion or amalgamation with its neighbours, so completely joining with each other as to leave no line of demarcation to tell the curious tale. In this way it becomes encrusted in large masses on floating timber and the sides of docks and canals, or in large globular clusters in slowly moving streams, sometimes of a bright green colour, or in irregular-shaped bodies of a whitish appearance, attached to the stems and leaves of plants. The peculiar irregularity of this last form forcibly reminds one of the chalk flints, and when it is remembered that these are fossil marine Sponges the coincidence is interesting as incidentally furnishing evidence of common origin.

One cannot speak of Sponges without at the same time speaking of spicula. Yet the spiculum is not an essential adjunct of Sponge life, as we all know by daily experience of the toilet Sponge,

which owes its own peculiar value to us by the absence of anything hard.

The beautiful unity and harmony which pervades all nature may be illustrated in endless instances; but in none is it more manifest than in the intimate relationship between the living forms and the mineral atoms that surround them. Thus silex, lime, iron, and other mineral substances are held in solution in the water (the water may be in the form of ponds, rivers, lakes, seas, or diffused in the earth or in the air), and in this condition are always available for the uses of animal and vegetable life. The living protoplasm, which is the "physical basis of all life," is ever taking up and assimilating this fine mineral matter into the several structures which constitute its bodily frame. Animals and plants alike require it, in ever-varying proportions according to their kind, in the formation of bone, shell, horn, hair, and other matters, and thus our Sponge largely avails itself of this ever present material in the construction of its spicular investment or embryo skeleton.

In *Spongilla* the spicula are of two kinds, one the amphidiscus, or double-disc cogged-wheel-like

form seen in the seed; the other the needle sort, investing the external tissue. In both cases they are formed of silex, and of very simple construction. There are, however, many forms of spicula in the great Sponge family; and commencing with the lowly form now before us, we might trace their development in endless diversity, from simple needle, or thornlike bodies, up to their marvellous development and complexity of arrangement in the beautiful *Euplectella*, or Venus's flower-basket, of the Manilla seas, which forms so prominent an object of beauty in our own homes.

XVI.—NATURE'S JEWELS.

"I hold it of little matter
Whether your jewel be of pure water,
A rose-diamond or a white,—
But whether it dazzle me with light."

"Tell them, dear, that if eyes were made for seeing,
Then Beauty is its own excuse for being."—EMERSON.

A GLASS slide, on which are mounted a number of Diatoms, carefully selected and artistically arranged, suggests the heading of this vignette. To the naked eye, the whole group appears as but the faintest speck on the glass. Only a relatively low power enables us to see them all at one glance under the microscope but this view is enough to evoke the joyful acclamation, "*Gems! Jewels!* Who would have thought it?" We increase the magnifying power, and now we can see only one at a time, but by shifting the stage we bring them one after another under observation; and now a

thousand additional beauties of structure or engravings on them are revealed. They will bear any amount of amplification; and the more they are scrutinized, the more beautiful and exquisite the markings are seen to be.

Gems and jewels suggest the ideas of rarity

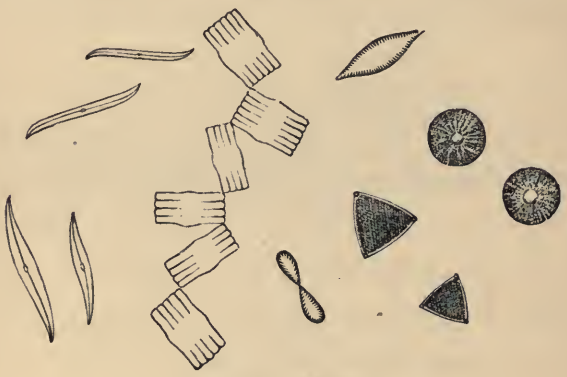


FIG. 26.—*Diatoms.*

and preciousness, but only the latter term applies to these, for not only are they not rare, they are, on the contrary, the most numerous and the most widely diffused of all material objects; and that they are costly or precious can only be inferred or declared of them when their functions, their formation, and the offices they perform in the general economy of nature, are understood. They are then seen to

be precious in a natural sense—not, indeed, as we speak of "precious stones," but rather as we regard the prime essentials of existence—even as air and water, which, although so common, are yet so precious that we cannot do without them.

But we are somewhat anticipating our subject, for what we have hitherto spoken of are only the "remains," so to speak, of the Diatoms—the outer covering — the external skeletons — the shields, plates, shells, and valves, as they are respectively named. And as to these, one may adopt the language of Lane Clarke, and say, "As the wondering astronomer discovers the infinite worlds revealed in unfathomed space, and sees star after star arise in countless myriads within the dim and distant nebulæ; as his mind bows down overwhelmed by the sense of the Omnipotent Creator's dominion and guidance of all those glorious orbs: even so the microscopist bends in astonished awe before the infinitude of God's works in the uncountable varieties and exquisite beauty of the minute Diatoms." Externally the Diatom consists of two plates or valves, united or kept in opposition to each other by a connecting zone—or rather, by two

connecting zones or girdles, which overlap each other at their free extremities. These zones are of great importance, as we shall presently see, and therefore their structure must be clearly understood. One zone would be enough if the object were merely to keep the valves in position, and therefore the fact of there being two is very suggestive. On close examination it is seen that, although not actually united to the valves, yet that on one side the zone is more firmly adherent to the valve with which it is in contact than to the zone it overlays. This overlapping sometimes gives the zones the appearance of an intermediate valve, or the whole frustule that of being a compound triplicate; the double structure, where they lie over each other, being of course less transparent than on the parts immediately in connection with the valves, on which there is no overlapping.

This bivalve shell with its girdling zones encloses a soft organic substance, the nature of which has been the subject of much dispute. Sufficient for our purpose here to say, that it is generally of a bright golden yellow, which colour it imparts to the external shell, and that it is the

seat of life, and of all the wonderful functions of which the whole Diatom is the agent. Although the Diatoms vary greatly in form, the structure here indicated is common to all. In some forms there is an additional external investment, consisting of a mucous or gelatinous substance, and in which they lie imbedded, side by side or end to end, in filaments or chains of various patterns; or they are attached by their angles in a zig-zag manner; or aggregating in masses, they build up a fairy tree-like or frondose form, or group in irregular bosses around the stems of plants. Although the Diatom exhibits these social tendencies in a greater or less degree throughout its vast species, yet each one is perfectly distinct in all that pertains to its own individual life, and in the majority the association is only that of free companionship with its fellows.

The especial importance of the girdling zones is only fully seen in connection with the propagation or re-production of the Diatom. Self-division is the common method here, as it is also with all the humble forms of life—and for that matter of all the higher and more complex beings, whether of animal or vegetable nature—the only difference

being that in the Diatoms and such like forms this process affects—or rather, involves—their whole being or individuality, whereas in complex organisms it is only a process of growth, a multiplication of cells from which the whole compound structure is built up.

Self-division in the Diatom, however, is not the simple and easy process which it is generally seen to be in most other minute existences; and for this reason, that it is invested with a material that does not grow *pari passu* with it. In other words, the valves are composed of pure silex, and incapable of participating in the process.

These two silicious valves bound the inner life substance, which latter grows and expands, and would undoubtedly burst its shelly investment if there were no other means of overcoming its resistance. This is furnished by the zones, which, as before observed, overlap each other, apparently for this very purpose; for when the pressure of growth from beneath is brought to bear against them, they are able to yield to at least the extent of the overlap without exposing the soft cell substance beneath. In this way room is given for the living cell to grow,

and eventually to divide. Before this takes place let us, in imagination, take another look at the position of affairs. There are the valves, lifted up and pushed aside, while the zones protect the new formation or cell growth, on which a longitudinal constriction, gradually deepening, embraces the whole contents. On this, the primordial utricle or membrane is being unfolded, completing the division. And now on this membrane the wonderful tracings and sculpturings, the exact pattern, or rather, copy, of the parent valves, are developed. The whole presently becomes silicified, and a new valve is formed. The same process is of course going on on the other side; and when completed, two Diatoms appear where only one existed before, each one having an old valve on one side and a new one on the other. We are watching a Diatom of the linear form. The division is effected, though for the moment the appearance is that of a double Diatom. Presently an opening commences at the forward extremities, as they move slowly along together, which, gradually expanding, at length terminates in final separation, and each Diatom proceeds alone on its destined course.

There is here no decay or dissolution; the new life and the old are blended and carried forward in the increased number of individuals; and if this process could be maintained *ad infinitum* it is evident they would never die, but would fill the universe with their ever-increasing numbers.

Amazing numbers are indeed produced in this way, for although the process of self-fission takes about twenty-four hours in each case, yet as long as it lasts it proceeds in a geometrical ratio, and the calculation is, that the progeny of a single Diatom in one month reaches the enormous number of one thousand millions of individuals. But Nature imposes a limit on growth, or cell-multiplication. The favouring season expires, or the exhausting and resting period is reached, decay supervenes, and dissolution ends the individual life. Before this, however, provision has been made for the recommencement of the life-cycle by another process, which is not that of growth or mere multiplication, but is essentially reproductive. This is by conjugation, or the union of the contents of two cells. Two Diatoms are seen to approach each other, and after a time

become surrounded by a gelatinous or mucous matter which holds them together. The valves of each Diatom now dehisce or gape, and the endochrome, or cell contents, of each flows out and mingle together, forming a globular mass, which gradually assumes the parental form, only much larger; or the new body thus produced may assume a form unlike that of its parents. In either case, however, it is only transitional in its nature—or rather, it is the fruit or seed whence the new generation is to spring. By-and-by, it will break up or open, setting free the myriad brood of embryos or *gonidia, i.e.*, spores or buds, which "either remain free or surround themselves with mucous, forming a pellicle or stratum, and in a definite but unascertained period reach the mature form," when they become invested with the silicious valves and zones, and consequently cease to grow or enlarge, except by the process of division already described. Something like an alternation of generations has also been observed in some varieties, one form producing buds, which in their development assume forms unlike their parents, and these producing yet other differing ones, which in their turn reproduce

the original. These intermediate forms having been mistaken for new species, have led to over-numbering the latter. There are many modifications of the *modus operandi* in both processes of *division* and *conjugation*, but although of great interest to the scientific student, are yet involved in too much obscurity for our purpose here.

One of the most interesting features in the Diatom, and one which has led to much speculation, is that of its movement. It has not been observed in all Diatoms, but in those in which it occurs it is very remarkable and full of interest. No loco motive organs or any other agency is seen, although the very highest powers of the microscope are used, "yet it moves," and it is an extremely interesting sight to see a number of these golden-coloured fairy-like boats without oars or paddles or any other visible propelling agency, gliding hither and thither in slowly measured time, over the surface of the miniature sea—now forwards and backwards in a strictly measured and definite distance in fair weather sailing, then turning, and jerking, and rolling, as if an invisible storm agitated the waters. In one species the movement is of the most singular

nature—*i.e.*, *Bacillaria Paradoxa*, which is one of the filamentous species and is found in fresh and brackish water. It consists of a number of frustules, *i.e.*, Diatoms, arranged in a close sort of connection

FIG. 27.—*Bacillaria Paradoxa.*

by some invisible medium; and as we now look at it, resembling a number of rods side by side, we are reminded of the "Pan's pipes," or showman's whistle, seen in our boyhood at a country fair. Scarcely, however, is the idea suggested

than a change in position is effected. One pipe makes a forward movement, followed by the next, and next, throughout the entire series, until an almost straight and rigid rod-like form is produced; then a pause, and a backward movement is begun, while the hindermost is at the same time moving forward, so that each half of the row is moving parallel to the other in opposite directions, the centre remaining stationary. Now an impediment is encountered and pushed aside; by-and-by another which cannot be moved comes in the way, and then the whole line of Diatoms pauses, but only just so long as the forward movement would have taken, and then they return. Again and again is the journey attempted, and as often foiled half way by this obstacle, yet there is no swerving, no turning aside for another path, no giving up the endeavour. *Our* patience is, however, exhausted, and so we lift the thin glass cover, and with a fine needle "clear the road" for our persevering acquaintance. The movement is slow but regular, and never did stage coach keep better time than our *Bacillaria Paradoxa*.

The cause of this, and of the movements

generally in the *Diatomaceæ*, is somewhat of a puzzle, and in this connection one is apt to ask whether the beings we are observing are of animal or vegetable nature? Here there is considerable diversity of opinion among the authorities, for while some think that their animality is beyond a doubt, others, and these the majority, are certain that they belong to the vegetable kingdom; the truth probably being that they belong to both, but are not absolutely one or the other. It is time that naturalists recognised in popular descriptions the fact, of which they are so well aware, that the phrase "animal and vegetable kingdoms" is not of divine authority, but purely of human invention. It is well known now that there is no sharp dividing line between animal and vegetable, where the one ends and the other begins; but that on the contrary, on this border-land the two blend into each other—plant-animal and animal-plant, being well recognised in numerous instances, of which also the Diatom is probably one. The various keen disputes, however, have not been altogether fruitless, for both parties, in order to sustain their own special view, have probably brought closer obser-

vation to bear on their investigations, and have thus elucidated many points of structure and phases of life which might otherwise have been overlooked.

Thus, on the one hand, the peculiarities of the Diatom's silicious valves, which seem to be perforated with minute foramina, or holes, have been watched with almost feverish earnestness, in order to discover whether or not any filmy processes ever protrude, which might not only account for their movements, but go a long way to prove their animal nature; and some observers have even asserted that they have seen them. Even Julias Sachs, an eminent authority, who classes them (the Diatoms) among the vegetable tribes, thinks it probable that it is by means of such protrusion of the internal soft organic matter that their creeping and crawling movements are effected. On the other hand, the advocates of their vegetable nature find not only that the special structure and functions which the other side regard as peculiarly animal are also found in undisputed vegetable organisms, but also that they possess other undoubted vegetable characteristics, which are but rarely found in conjunction

with admittedly animal bodies, and that these immensely preponderate over their animal or semi-animal attributes. Thus, the Diatoms evolve oxygen, rise to the surface of the water in sunlight, and in the Antarctic Ocean (as we are informed by Dr. Hooker) their vegetable nature is of such importance that but for them the water, in the utter absence of other vegetables, could not be purified from the carbonic acid caused by animal respiration and decomposition, and that thus by their immense numbers they not only furnish an abundance of vegetable food to the herbivorous mollusca, and other inhabitants of the sea, but that without them the balance of nature would be so disturbed as to render the continuance of animal life impossible in those regions. Yet they exist in equal, or even in greater abundance, in tropical seas. Dr. Wallich found them, with but little interruption, to the depth of some feet throughout six degrees of longitude in the Indian Ocean, and there they were of such gigantic size as even to be visible individually to the naked eye. Thus the argument for their vegetable nature has a twofold aspect; for if vegetable, by analogy we

should expect their growth to be greater and more brilliant in the tropics—which is the case; while in the polar regions their peculiar structure fits them to supply the place of other vegetable life, and makes them of prime importance as an article of food, and natural equilibriating agency. Still, if *wholly* vegetable, one would hardly expect to find them so abundant under conditions so unfavourable to vegetation as the Antarctic Ocean.

What we become actually aware of in this discussion is the fact of their immense importance in the order of nature, for which their peculiar combination of both animal and vegetable nature renders them the unique agents they are.

We might go further, and say that the Diatom is not only a combination of animal and vegetable nature, but that it represents in its structure the mineral kingdom also; for are not its valves composed of silex, or flint, which it can only obtain from the mineral kingdom, and which constitutes the greater part of its bulk, if such a word may be applied to such minute existences.

In the reproductive process the germs of future generations being secured, the parental cells die,

and their almost indestructible coverings fall to the bottom of the water, forming in many cases vast deposits on the floor of the ocean, the mouths of rivers, and the beds of fresh water lakes, &c. Or the living Diatoms are devoured by fishes, and these in their turn by birds; and though thus subject to a double digestive process, their silicious valves turn up again in guano, and when cleaned and mounted are objects of great beauty. Indeed it is the casket, and not the priceless life gem it contains, which has attracted most attention to the Diatom; and this is not to be wondered at, or even deplored, when its varied and beautiful form and exquisite sculpturing are considered.

Variety is a general law in all kinds of life, but in many of its lowly forms (as we have seen) this is characterised by great irregularity. The reverse is the case in the *Diatomaceæ*, where symmetry is the universal law—the valves and the engravings on them being formed with mathematical accuracy, and matchless artistic delicacy and skill. Any attempt, however, at verbal description not only cannot do justice to this part of our subject, but would rather damage it than otherwise.

So, in the absence of elaborate and expensive drawings, we can only say to the reader, examine them for yourself; put them under the most searching gaze, and with the highest powers of the microscope, and the more you scrutinise, the more beauty will be revealed, and the greater will be your wonder and admiration.

Other gems and jewels rare, will fade into inferiority beside these productions of nature. The midnight lamp grows dim as the hours pass by and your whole being is rapt in adoring contemplation. The dull earth is transformed, not in imagination only, but in sober truth to your mind, for is it not really encrusted all over with these sparkling gems, far surpassing all the dreams of magician or poet?

One hundred millions of Diatom caskets do not weigh a grain. A single cubic inch of the polishing slate in Bohemia, which exists in beds or strata of fourteen feet in thickness, contains forty thousand millions of them. Vast and extensive tracts of the earth's crust is formed almost entirely of them. The city of Richmond, in Virginia, is built on a bed of *Diatomaceæ* eighteen feet in thickness.

They stand the wear and tear of the elements for thousands of years. They are found in pumice-stone, and in the ashes of both active and extinct volcanoes, in meteoric dust, in the stomachs of fishes and birds, in the deepest recesses of the ocean, in the pancake ice of the polar regions, amid the mangrove swamps of the tropics, on the mountain tops, and in the valleys beneath. Earth, air, and water—every clime and country on the globe—are penetrated by Diatoms, either fossil or living, or both.

Diatoms in their living state constitute a kind of almost universal food; from the humblest infusorian up to man himself, all partake of them in one form or another; and even their silicious remains, mixed and baked with common earth, are sometimes the food of starving man; while the Japanese make a delicate and nutritious soup with them in their living condition, along with certain kinds of sea-weed. They also add greatly to the fertility of the soil, while at the same time increasing its quantity. It is well known that the best guano is that in which Diatoms are most abundant, and that river deposits rich in diatomaceous remains are very

valuable as fertilising agencies. In the arts and manufactures they are brought into use as polishing powder, as the finest material for delicate metallic castings; and in the manufacture of porcelain they are invaluable.

As indicating the value and importance of the *Diatomaceæ* from a natural standpoint, or the value set upon these, her favourite jewels, by Dame Nature, we may mention the singular fact, that although found in a fossil condition in connection with the dawn of life on the globe, yet, in the words of Dr. Gregory, "We have no evidence that any species of Diatom has become extinct, as so many species, and even genera and tribes, of more highly organised beings have done." It is not pretended by these remarks that no new species have been produced, the reverse being well known, no form of life exhibiting greater varieties—but only as indicating their importance in that, through all the mutations of other forms of life, while they come and go, the Diatom, though evolving an almost infinite variety through thousands or millions of years, has been preserved, in all its original specific characters to the present time.

The multitudinous variety of figure and sculp-

turing in the Diatoms are beyond description, yet they all exist under a few general characteristic forms. Thus they are attached to each other by a stalk or pedicle, or coherent in chains and branching tufts, or isolated and free; and under these several forms or conditions of existence they assume an endless diversity of figure and markings, which to describe in detail far surpasses our skill. A few words strung together may, however, give some general idea of these diversities.

Thus as to their figures: they are wand-like, trapezoid, square, round, circular or like a pill-box, globular or spheroid, boat-shaped, oval, egg-shaped or ovoid, discoid, wedge-shaped, cuneate, triangular, rectangular, curved, twisted, sigmoid or undulate, arcuate, saddle-shaped, geniculate, alate or winged, lunate, &c., &c., &c.

Then as to the symmetrical designs or markings on the valves, some are hexagonal, others are marked in lines of round or oval dots. The markings on the discoid forms are generally the most beautiful, and in some the pattern is divided into six, eight, or ten compartments, all arranged round a common centre, and beautifully ornamented with

the finest and most delicate precision. In one—*i.e.*, *Arachnoidiscus Japonicus*, in which the valves are of a double nature, the external being horny, and the internal silicious—the markings on the external valve are after the pattern of the spider's web (hence its name), and on the internal, like that of a "circular Gothic window," both together forming a remarkable design, executed with marvellous delicacy and mathematical exactness.

Then there are the beautiful *Coscinodisceæ*, with numerous genera and species, not divided into compartments. In one species (*C. oculus*) the valves are marked with hexagonal areolæ or circles, in the centre of which appears a peculiar eye-like formation. Of other discoidal forms, such as *Calodiscus*, *Campylodiscus*, *Craspedodiscus*, *Eupodiscus*, *Hemidiscus*, *Hyalodiscus*, *Odontodiscus*, *Pododiscus*, *Stephanodiscus*, with their numerous species and varieties, as well as the immense number of other forms into which the vast realm of the *Diatomaceæ* are divided, we must forbear to speak further. The subject is too vast for such a little work as this, which aims only at awakening an interest in invisible life, and of indicating where or in what direction it may be gratified.

CONCLUSION.

"Once heave the ball from the hand, and one can show how all this mighty order grew. That famous aboriginal push is propagated through every atom, through all the races of creatures, and through the history and performances of every individual."—EMERSON.

THE word *invisible*, as applied to at least some of the forms of life here treated of, and notably to the Sponge, may appear to an objector as a misnomer. Yet, not to be hypercritical, he might say: "I understand that by this term you mean those forms of life which are invisible, or nearly so, to the unassisted eye, and though not literally correct, yet is sufficiently so for our ordinary every-day-life mode of speaking, in which considerable latitude of expression is allowed, and no misunderstanding results. But to speak of a Sponge, which can be readily seen, as belonging to this class of being is surely erroneous."

To answer such an objection one might at first admit the imputation, and be in harmony with the general impression on this subject. But we prefer, on the contrary—and this for a special purpose—to go behind the objection in order to answer it, and in so doing to ask the very old and oft-repeated question, not "What is *invisible* life?" but "What is *life?*" for it seems necessary to have some notion of the thing itself before saying anything of its qualities. Should we be surprised if told that *all* life is invisible? That, however, seems to be the case, though, of course, it was not with this idea that these sketches were commenced, or in this sense that they were named "*Invisible Life.*" The Sponge before alluded to affords a good illustration of the idea here sought to be conveyed; and whether happily or not, it has been the immediate agent in suggesting it in this connection. In the Sponge we see with our naked eye almost as much as with the microscope, so far as its exterior is concerned, yet no sign of life appears. There is the dull, opaque, immobile mass of matter, but no visible action—no locomotion; not even is any organisation visible. The mystery of its being, its living activities, are

all hidden beneath that very visible exterior; and in this sense there is no mistake in classing our Sponge life with the invisible. Still, this illustration, so far, is only an approximation to our idea. To make the matter plainer, let us say that although we are daily looking on natural objects, or rather on living forms, as bird, beast, flower, and tree, yet that in reality we see only the external forms, underneath which the real life is hidden. We perceive the organised structure, but not the living matter—the product, but not the agent.

Cutting, or tearing open the Sponge, we can, as previously described, by the aid of the microscope, and that alone, see the otherwise invisible agents, or the living forces, the nearest approach to actual living matter, which in its essential purity is without any structure or organisation whatever. This Amœboid matter, or protoplasm, is then the hidden basis of life, animal and vegetable, the invisible agent of all organisation. It is a singular fact that this living matter cannot be analysed, for the instant this is attempted its essential quality, that which is its prime element, eludes our grasp:

the life has fled, and our analysis may indeed proceed, but the result will be that of dead, not living material.

The chemist may give us the constituent elements of this dead matter, may possibly—though as yet he has not done it—reproduce it in his laboratory by methods not ordinarily employed by nature, yet the living element, the one thing needful, will be lacking, and he will be as far off as ever from the unapproachable cause: the absolutely invisible life of the universe, "whom no man hath seen or can see," but "in whom we all live and move and have our being," in whom centres all our confidence, all our joy in the present, and hopes in the future.

Finally, the author would have his work read in the spirit in which it is written, which cries, "Give me truths, for I am weary of the surfaces," in the spirit of the men of old: preferring things to names. The prevailing spirit of the present time is that of *gain*, and which, when applied to the study of nature, results in a reproduction of the "apples of Sodom"—beautiful in appearance, but yielding only bitterness and dust, when appropriated by

its votary. This blighting experience is very happily expressed by Emerson, thus:—

"Our eyes
Are armed, but we are strangers to the stars,
And strangers to the mystic beast and bird,
And strangers to the plant and to the mine.
The injured elements say 'Not in us;'
And night and day, ocean and continent,
Fire, plant, and mineral, say 'Not in us,'
And haughtily return us stare for stare;
For we invade them impiously for gain;
We devastate them unreligiously,
And coldly ask their pottage, not their love.
Therefore they shove us from them, yield to us
Only what to our griping toil is due.
But the sweet affluence of love and song,
The rich results of the divine contents
Of man and earth, of world, and loved and lover,
The nectar and ambrosia, are withheld;
And in the midst of spoils and slaves, we thieves
And pirates of the universe, shut out
Daily to a more thin and outward rind,
Turn pale and starve."

THE END.

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